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A structural soil surfacing (FOMAT), consisting of a rigid polyurethane foam core sandwiched between two fiberglass reinforced plastic (FRP) layers, is being developed to fulfill a need for a designable, heavy-duty, expedient surfacing for Marine Corps amphibious landing applications. In analytical and laboratory investigations, FOMAT showed very good potential for meeting expedient surfacing requirements. The FOMAT constructed of 15- and 20-pcf-density foams will adequately carry F4 aircraft wheel loadings as determined from finite

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element computer analyses and plate loading tests in a mechanical simulated subgrade. Tests performed on FOMAT with 20-pcf foam core showed that it meets or exceeds F4 aircraft arresting gear hook/impact and jet engine heat/blast performance specifications for a heavy-duty matting. Construction of FOMAT under field conditions indicated a problem with bonding of the polyurethane foam core and the bottom FRP layer, causing premature termination of simulated F4 aircraft wheel traffic tests on eight FOMAT panels located on heavy clay, lean clay, and sand soils. FOMAT panels consisting of 15- and 20-pcf density and 1- and 2-inch-thick foam cores were subjected to the traffic loadings. At a maximum of 40 passes on two panels of 2-inch-thick 15-pcf and 2-inch-thick 20-pcf foam core, a wheel deflection of 1 inch on the FOMAT surface was experienced. Development of field construction techniques to insure positive bond between the foam core and bottom FRP layer is recommended.

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FOMAT, consisting of a rigid polyurethane foam core sandwiched between two fiberglass reinforced plastic (FRP) layers, is being developed to fulfill a need for a designable, heavy-duty, expedient surfacing for Marine Corps amphibious landing applications. In analytical and laboratory investigations, FOMAT showed very good potential for meeting the requirements. Finite element computer analyses and plate loading tests in a mechanical simulated subgrade indicated FOMAT constructed of 15- and 20-pcf-density foams will adequately carry F4 aircraft wheel loadings. Tests with FOMAT with 20-pcf foam core met or exceeded F4 aircraft arresting gear hook/impact and jet engine heat/blast performance specifications for a heavy-duty matting. FOMAT constructed in the field did not bond well, resulting in premature termination of simulated F4 aircraft wheel traffic tests on eight FOMAT panels located on heavy clay, lean clay, and sand soils. Development of field construction techniques to insure positive bond between the foam core and bottom FRP layer is recommended.

CONTENTS

INTRODUCTION

Objective

The objective of the investigation reported herein is to develop an expedient surfacing system for Marine Corps airfield, road, and logistic support area applications. Heavier duty surfacings than FRP are needed to accommodate large container/material handling/transporting equipment and aircraft. These surfaces must also be logistically superior than present metal mattings. This report documents the results of developmental efforts to date in meeting this objective.

Background

In the execution of Marine Corps amphibious landing operations, aircraft and other heavy equipment (e.g., material and container handling and transporting) will be involved. Trafficable surfacings are required for effective operation of such aircraft and heavy equipment. These surfacings must have the following characteristics:

(a) Rapid placement

(b) Native material not required

(c) Trafficable within an hour after placement

(d) Able to carry loadings without damage

(e) Smooth and impermeable

(f) Easily and quickly repairable

These criteria evolve from requirements to construct, operate, and maintain such surfacings under adverse combat conditions. Sandwich surfacing composed of polyurethane structural foam between outer layers of fiberglass-reinforced polyester (FRP) (Figure 1) appears to be an excellent candidate for the surfacing to meet the above criteria. Accordingly, the Civil Engineering Laboratory (CEL) is pursuing the development of this surfacing, identified as FOMAT.

Conventional surfacings such as asphalt and portland cement concrete do not completely satisfy the above criteria. Both rely heavily on native material (sand and gravel) as vital components in their construction. These native materials may require extensive processing or may have to be hauled in over a long distance. Additionally, concrete takes many days to cure before it is trafficable. Thus, these surfacings are not satisfactory for use in initial Marine Corps landing operations.

Specialized matting has been developed previously for constructing heavy-duty expedient surfacings for military applications. These mattings are constructed of steel or aluminum. Although effective as a surfacing for their particular applications, these mattings possess some critical deficiencies. These mattings (1) are bulky and thus occupy valuable shipping space, (2) have seams and joints through which water can seep to weaken and erode the subgrade soil and through which soil can be pumped and eroded away by jet blast and wind, and (3) are difficult to repair or replace. Therefore, these specialized mattings do not completely satisfy all of the criteria specified previously.

FOMAT as an expedient surfacing for airfields and other areas used by heavy equipment promises to meet all of the criteria specified. Polyurethane products are highly developed and are commercially available in liquid form for use in fabricating foam layers to desired dimensions and strength. In other developmental efforts, the Marine Corps has acquired an Advanced Multipurpose Surfacing System (AMSS) for roadways based on FRP as the sole surfacing [1,2,3]. This same system is used for the outer FRP layers in FOMAT construction. Thus, the structural components used in FOMAT construction are already highly developed. The combination of these components into a sandwich structure extends their load-carrying capability by optimizing use of their desirable properties.

The basic principle of the sandwich structure in carrying or supporting a given load is analogous to a wide flange or I-beam under similar loading [4]. With a beam, the flanges experience tension or compression (depending on the loading and location of the neutral axis), and the web transmits shear load to the beam supports. The beam configuration of web and flanges results in an efficient and economical structural member with a minimum of weight-to-load-carrying-capacity ratio. The concept of FOMAT is to utilize this basic principle of the beam to achieve a surface with an efficient weight-to-load-carrying-capacity ratio. In the FOMAT structure, the outer FRP layers and the inner polyurethane core are analogous to the flanges and web, respectively, of a beam.

Since the concept of FOMAT met all of the desirable criteria and possessed the best potential of meeting program objectives, the development of FOMAT as an expedient surfacing system has been pursued. The developmental effort thus far has included preliminary laboratory model studies, heat/blast test, hook/impact tests, and aircraft wheel traffic tests.

FOMAT DESCRIPTION

Material Components

In all of the experiments performed and reported here, each FOMAT specimen was constructed using the same material components, which are summarized in Table 1. A close accounting of the material used, however, was not feasible since some of the raw materials - such as the resin and

catalyst - have short shelf lives. As a result, the materials used in each experiment may have originated from different "batches" during manufacturing and were at different stages of their shelf lives. It is believed that variations in the batches and storage time before use of each material have little effect, if any, on the completed FOMAT specimen.

Several combinations of density and thickness of the polyurethane foam core were used in constructing FOMAT test specimens used in these experiments. They were:

Density (lb/ft^3)	Thickness (in.)
15	2
20	1 & 2

The outer FRP layers (in all cases) were composed of two layers each of fiberglass matting. The completed FOMAT sections using the above foam thicknesses and fiberglass layers were approximately 1-1/2 and 2-1/2 inches thick.

Several types of fiberglass matting construction were used in fabricating FOMAT test specimens. Early in the program, fiberglass matting consisting of chopped random fibers was used. Subsequently, a matting type as shown in Table 1, consisting of woven fiberglass fibers on one side and chopped random fibers on the other, was used. The woven fiberglass layer is referred to by the fiberglass industry as "woven roving"; this same terminology is used in this report. The net weight in ounces per square foot of the first type of matting was approximately the same as that shown in Table 1, which is for the second type of matting.

Laboratory Specimen Construction

In general, the procedures used for constructing laboratory FOMAT specimens is as described below. Each laboratory specimen was constructed as follows:

1. The preformed foam billet of required thickness was placed on a horizontal surface.

2. A piece of fiberglass matting slightly larger in dimensions than the foam core was placed on the foam with woven roving side upward.

3. Sufficient resin was mixed and poured onto the fiberglass.

4. The fiberglass was immediately rolled with a small hand roller.

5. A second fiberglass matting was then placed onto the previously installed fiberglass also with woven roving side upward.

6. The remaining resin from the above batch was then poured on the fiberglass and the fiberglass rolled in the same manner as the first layer.

7. The resin was permitted to cure (approximately 15 to 30 minutes). The half-completed FOMAT sample was then inverted to install the fiberglass layers on the other side. Installation of the fiberglass layers on this second side was performed in the same manner as with the first side.

Field Panel Construction

The construction of field FOMAT test panels followed a slightly different procedure than that described above for laboratory specimens. After leveling/smoothing off the ground surface, the following procedure was used to construct 8 x 12-foot FOMAT panels using the Marine Corps Low Rate Spraying Unit:

1. A thin coating of resin was sprayed over the ground.

2. The first layer of fiberglass matting was placed with woven roving side down.

3. Resin was sprayed onto the fiberglass.

4. The fiberglass was then rolled with a large long-handled hand rolier.

5. Before the resin in the first fiberglass layer had gelled, a second fiberglass layer was placed with woven roving side down.

6. Resin was sprayed onto the new fiberglass.

7. The fiberglass was again rolled.

8. Immediately more resin was sprayed onto the fiberglass in sufficient quantity to insure good bond between the installed FRP layers and the preformed 4 x 4-foot polyurethane foam core billets which were next placed and weighted down.

9. After the resin had cured, the weights were removed and a layer of fiberglass matting was placed on the foam with the woven roving side up.

10. Resin was sprayed and the fiberglass rolled.

11. Immediately another layer of fiberglass matting was placed with the woven roving side down.

12. Resin was sprayed and the fiberglass rolled.

The FOMAT panels as constructed in the field differed somewhat in terms of physical dimensions of the bottom FRP layer from those fabricated in the laboratory. The thickness of this FRP layer varied with the permeability of the soil. As the permeabiltiy of the soil increased, the thickness of the bottom layer (which included some resin saturated soil) increased.

EVALUATION TESTS AND RESULTS

Preliminary Analysis

To determine the applicability of FOMAT as a structural surfacing, two sections were analyzed using a finite element computer code developed at CEL for layered pavement systems [5]. In the analysis, a linear elastic model is assumed along with the following conditions: (1) the surfacing had an infinite width, (2) the supporting soil was a cone frustum with sides sloping outward at 30 degrees from the vertical and, (3) the outer boundary of the cone was free to move vertically but was restrained horizontally.

The FOMAT configurations analyzed were: (1) 1/4-inch-thick FRP faces with a 2-inch-thick 20-pcf foam core, and (2) 1/4-inch-thick FRP faces with a 2-inch-thick 10-pcf foam core. The 20-pcf core configuration was considered to be the upper limit of core density that still retained a logistics advantage over AM-2 matting. The second configuration, with the 10-pcf core, was felt to represent the lower limit of strength to support the required loads.

The load applied by the F4 aircraft was used in this analysis. The F4 tire print was simulated by a uniformly loaded circular area 11.5 inches in diameter. A tire pressure of 250 psi was utilized yielding a total load of 26,000 pounds.

Three subgrade conditions were analyzed to cover a range of possible conditions. Subgrades with California Bearing Ratios (CBR) of 4, 15, and 50 were selected. To utilize these subgrade strengths in the finite element computer code, it was necessary to derive equivalent elastic moduli for the subgrade. The moduli were based on experimental data in a previous CEL study of FRP surfacing [6]. The moduli used were:

CBR	Subgrade Elastic Modulus	Poisson's Ratio
4	1,400 psi	0.20
15	3,750 psi	0.20
50	14,400 psi	0.20

The outputs from the computer analyses were compared with the ultimate strengths of the FOMAT component materials. The results of this comparison are shown in Table 2. Based on the values of the ratio of ultimate strength to calculated stress, it is apparent that the 10-pcf foam would be at incipient failure under compressive loading equivalent to that used in the analyses. However, the same loading on the 20-pcf foam would result in stresses well within the load-carrying capability of the foam. A decision to pursue further developmental work with 15- and 20-pcf foam was made, based on this analysis.

An additional computer analysis was made using AM-2 matting as the surfacing on a CBR 4 subgrade soil. The deflections from this analysis

were compared with those obtained from the analysis on the 10- and 20-pcf foam core FOMAT. The results of this comparison are shown in Figures 2 and 3. FOMAT deflected considerably more under similar conditions than did AM-2 matting.

Laboratory Load-Bearing Test

Tests were performed in the CEL model subgrade on 4 x 4 foot FOMAT panels constructed of 2-inch-thick 20-pcf foam sandwiched between two layers of 1/4-inch-thick FRP. The objective of these tests was to validate the preliminary analysis made by the finite element computer code and to determine the behavior of the panels under simulated field loading conditions. Also included in the tests was a 2 x 6 foot section of AM-2 matting.

Prior to testing of the FOMAT panels, investigation of construction techniques was made to obtain optimum bonding of the FRP and polyurethane foam core. Flexural beam tests on 2-inch-wide beams (as shown in Figure 4) were performed on specimens to assess each technique. The construction technique described earlier in the section "Laboratory Specimen Construction" was finally selected.

The 4 x 4-foot panels were tested on the "mechanical subgrade," which simulates the action of natural subgrade by means of a spring-and-plunger arrangement. The stiffness of the subgrade support is determined by the size of the springs used (in these tests k = 155 psi/in.). The mechanical subgrade is approximately 10 feet square with a flooring of 3,600 2-inch-square steel plates mounted in 60 rows of 60 plates each. Each plate is attached to a plunger which is supported by a calibrated spring. A spring and plunger assembly is shown in Figure 5.

The loading system used for the FOMAT tests consisted of a 100,000-pound-capacity jack and electronic load cell and the overhead reaction frame. The simulated F4 load was applied on a 12-inch-diameter plate and the deflections under load were measured with dial indicators mounted on a rigid beam that had end supports outside the loaded area. The dial indicators were positioned at two diametrically opposed edges of the steel plate and on the FOMAT at 9, 15, 22, and 32 inches from the center of the plate. A typical FOMAT test set-up is shown in Figure 6.

The deflections produced by loading the FOMAT panel to failure on the mechanical subgrade are shown in Table 3. The FOMAT panel failed at an ultimate load of 71,750 pounds. The foam core and the FRP faces remained bonded through the loading cycle. A plot of the deflections at 30,000 pounds loading for the FOMAT and for the AM-2 matting is shown in Figure 7. The deflections noted in Figure 7 for the laboratory load test at 30,000 pounds on the FOMAT compare closely with the results from the computer code plotted in Figure 2 for a load of 26,000 pounds on a CBR 4. The deflections for the AM-2 matting were greater under actual load than indicated by the computer code; this difference is attributable to the elastic moduli assumed for the matting and used as input to the computer program.

Results from these laboratory load-bearing tests indicate that FOMAT is capable of supporting loadings equivalent to an F4 aircraft wheel. When compared on an actual subgrade contact area basis, the deflection characteristics of the FOMAT and AM-2 matting are almost identical.

Jet Engine Heat/Blast Test

A J-57 jet engine was used at a test facility at the U. S. Army Engineer Waterways Experiment Station (WES) to determine the effect of heat and blast on 4 x 4-foot FOMAT panels. The test panels were positioned on a frame such that the engine exhaust stream was received at 90 degrees (perpendicular) to the panels. The desired exposure temperatures were obtained by varying the engine throttle setting and the distance from the exh ıst exit to the test panel. A general view of the test setup is shown in Figure 8.

Prior to testing of the FOMAT panels, blast temperatures on the test table were monitored with thermocouples on the table surface. Figures 9, 10, and 11 show the locations of the thermocouples on the test table and the respective temperatures for the nominal 500°, 750°, and 1,000°F test cycles that were used.

The FOMAT panels used in the test series were all fabricated with 2-inch-thick, 20-pcf foam cores sandwiched between 1/4-inch-thick FRP. The dimensions of the test panels were 4 foot by 4 foot by 2-1/2 inches. All the panels were fabricated with five imbedded thermocouples to indicate heat transfer within the specimen during exposure to the jet engine blast. The panels were subjected to blast temperatures of 500° and 750°F for five 10-second exposure cycles and for ten 1,000°F 10-second exposure cycles. The time between exposure cycles was 4 minutes in all cases except as noted in Table 4. Blast pressure during the 500° and 750°F exposure tests was 1.5 psi and for the 1,000°F tests, it was 2.0 psi. During the blast tests, the heat transfer in the panels was determined by recording the output of five thermocouples molded at various locations in the panels. The resulting temperature measurements are shown in Table 4 for each of the test panels.

Panels 1, 2, and 4 were tested as fabricated; panels 3 and 5 were coated with Dow silicone rubber RTV 732. The resin on the panels had not cured completely as the surface resin was soft and sticky. During the 500° and 750°F exposures the panels appeared to have completed curing as the surfaces, after exposure, were those of a properly cured polyester resin.

Visual inspection of each panel was made after the exposure cycles. There was no indication of material loss as a result of the 500° and 750°F exposure tests. In the 1,000°F exposure test however, resin loss from the panel surface was noticed. All surface resin was blown off, and the fiberglass woven roving became exposed. However, the fiberglass did not become unbonded from the lower FRP material. An example of blast and temperature effects on one of the FOMAT pane'- (panel no. 1) is shown in Figures 12, 13, 14, and 15, which are pictures of the panel prior to the start of the tests and after completion of the 500°, 750° and 1,000°F tests, respectively.

The results from these tests show that FOMAT satisfactorily meets requirements to resist heat and blast from jet engine exhaust. The Qualitative Material Requirement (QMR) for prefabricated airfield surfacings specifies that heavy duty landing mats shall be capable of withstanding aircraft blast effects of 700°F for 10 seconds resulting from operation including maximum takeoff using afterburners [7]. The FOMAT panels tested withstood blast effects of 750°F for 10-second duration for each of five cycles without loss of material or other detrimental effect. The blast effects withstood by the FOMAT test panels are higher than the exhaust blast measured for the V/STOL AV-8A Harrier aircraft [8].

Arresting Gear Hook/Impact Test

The TC3 catapult facility at the Naval Air Engineering Center, Philadelphia, Pennsylvania, was used to determine the effect of impact from an aircraft arresting gear hook on FOMAT panels. An overall view of the test facility is shown in Figure 16. The catapult assembly on which the test FOMAT panels were installed and the arresting gear hook are shown in Figures 17 and 18, respectively.

The QMR for prefabricated airfield surfacings specifies that critical areas of runways surfaced with heavy duty mat shall withstand five F4 tailhook impacts of 80 knots at equivalent 18-fps sink speed at the same location without structural failure due to rupture of the top surface of the mat [7]. The hook impact tests on the FOMAT panels were performed to determine if FOMAT can meet this performance specification.

The FOMAT panels used in the test section were all fabricated with 2-inch-thick, 20-pcf foam cores sandwiched between 1/4-inch-thick FRP. The dimensions of the test panels were 2 foot by 4 foot by 2-1/2 inches. Overlap joints in the FRP were positioned both transversely and longitudinally to the path of the arresting gear hook to simulate field conditions. Figure 19 shows a test panel before testing; Figure 20 shows the same panel at the completion of five cycles of the hook/impact tests.

Visual examinations were made of each FOMAT panel at the conclusion of each test cycle. Slight delamination of small local areas occurred on the surface of the FRP and were of a superficial nature. Structural delamination of the FRP from the foam core, however, did not occur. Since rupturing of the top surface or any other structural failure did not occur in any of the FOMAT panels, FOMAT meets QMR specifications for F4 tailhook impact for heavy-duty airfield surfacings.

AIRCRAFT WHEEL TRAFFIC TESTS

Traffic tests were performed on test FOMAT panels constructed inside one of the hangars at the Waterways Experiment Station (WES), Vicksburg, Mississippi. FOMAT panels constructed of different unit weights and thicknesses of polyurethane foam cores were installed over sand, lean clay, and heavy clay soils of various CBR values. A 30-kip wheel load was used to simulate an F4 aircraft traffic loading on each FOMAT test panel.

Construction of FOMAT Panels

A typical FOMAT test panel as constructed at WES for the traffic tests is shown in Figure 21. Each panel was constructed in a test pit 8 feet 1 inch by 12 feet 1 inch in plan and nominally 14 inches deep. The sides of each pit were vertical and were constructed of concrete; the floor of each pit was native, lean clay soil. Each pit was lined with a polyurethane sheet to prevent moisture migration into or out of the test soil. The test soils were backfilled and compacted into each pit in two lifts except for the sands, which were backfilled in one lift. After backfilling was completed, each soil was hand-graded to the elevation to allow the top surface of each finished FOMAT to be level with the top of the concrete boundaries. Thus, the test soil layer was nominally either 12-1/2 or 11-1/2 inches thick, depending on whether a 1- or 2-inch-thick foam core was to be installed. Each FOMAT panel was constructed according to the procedure described for field FOMAT test panels presented earlier in this report. As shown in Figure 21, six 4 x 4-foot foam cores of either 1- or 2-inch thickness were installed in each panel. Each fiberglass matting used was 6-1/2 feet wide and was cut into 8-foot lengths. Four such mattings (double layer with 1-foot overlap) were used in the bottom FRP layer as well as in the top FRP layer. In the same figure, the location of the 1-foot-wide fiberglass lap joint and the location and direction of the test track are shown.

The quantities of fiberglass and chemical components used in constructing the outer FRP layers of all FOMAT panels were as follows:

Fiberglass (Includes 210 ft^2 for FRP-only test pit)	3,573 ft^2
Resin	4,500 pounds
Weight ratio of catalyst to resin	0.012
Weight ratio of promoter to resin	0.008

The resin temperature at the time of spraying was 81°F. Approximately 1-1/2 hours were required to complete the construction of all test panels.

From the above data, it is seen that 1.3 pounds of resin per square foot of fiberglass were used. However, included in this figure is the indeterminable quantity of resin sprayed on the ground outside the FOMAT test pits to obtain the correct mixture by sight.

The results of the spraying were almost completely successful. Notes taken during spraying and post-spraying observations of each FOMAT panel prior to the traffic tests that are significant to data interpretation are presented in Table 5. All of the finished FOMAT panels had some air/gas bubbles beneath the surface FRP fiberglass.

The layout of each FOMAT test panel over each test soil is shown in Figure 22. Also shown are the thickness and unit weight of polyurethane foam used in the construction, the location and direction of the test

track, and the soil type and CBR. Figure 23 is an overall view of the completed FOMAT test panels prior to the traffic tests. The second white line from the left is the centerline location of the wheel.

Soil Data

Various tests were performed on the soils used in the test pits (1) prior to construction of the FOMAT panels, (2) immediately after construction of the panels, and (3) after completion of the traffic tests. The tests performed included the CBR, plate bearing, and airfield cone penetration. The results from the CBR and airfield cone penetration tests are summarized in Table 6. Results of the plate bearing tests performed on the three types of test soils installed in the pits and prior to construction of the FOMAT test panels are shown in Figures 24, 25, and 26. Results of the plate bearing tests performed on each FOMAT panel prior to the traffic tests are shown in Figures 27, 28, and 29. All of the plate bearing tests were performed with a 12-inch-diameter plate.

Test Setup and Procedures

Traffic loading was simulated with an F4 aircraft wheel mounted on the vehicle shown in Figure 30. The data on the tire used are as follows:

Manufacturer	B.F. Goodrich
Designation	Silvertown, Nylon Type VIII, Tubeless
Size	30 x 11.50 - 14.50 24-ply rating
Pressure	250 psi

The 30,000-pound wheel loading was obtained by loading the vehicle with lead weights.

Traffic loading was provided by driving the vehicle backward and forward, matching the centerline of the path of the loading wheel with the white line shown in Figure 23. The number of passes of the wheel and data from the measurements of the FOMAT surface elevations and deflections under loadings were recorded at selected intervals.

At selected numbers of passes, cross section and profile data were taken with a standard surveyor's level and a special level rod. All of these measurements were made with the wheel load off the test panels. A permanent bench mark located along the inside of the wall of the hangar was used as the reference datum for all of the collected data. The level rod was adjusted to zero while on this bench mark for all readings; thus, all of the readings were actual positive or negative elevation differences from this bench mark. Cross section measurements were made at 2, 4, and 6 feet onto each test panel. These locations represent either the midpoint of each foam billet or the joint between adjacent billets. Profile readings were taken along the centerline of the track.

Deflection readings were taken with the wheel load off and on each FOMAT panel during the first pass. These readings were taken at 2 and 4 feet onto each test panel. A special tripod which permitted the level to be located near the ground surface was used. While in the prone position, the operator took readings off a short* level rod that permitted the taking of readings beneath the load vehicle adjacent to the wheel. After the first pass, deflection readings were taken with the regular height tripod and long rod to determine the deflection of the FOMAT directly under the wheel. The height from the ground surface to the top of the wheel was measured as 25.5 inches. Elevation readings taken directly over the center of the wheel were corrected with the above height to determine the actual deflection of the FOMAT surface under the wheel.

Test Results

The performance of each FOMAT panel under traffic loadings is summarized in Figure 31 which is a plot of the number of passes of the loaded wheel relative to the average of before and after traffic soil CBR. Plotted in this figure are the number of passes experienced when a maximum deflection reading of 1.0 inch was obtained at any of the two locations where measurements were made. Exceptions were for CH-1-20 and CL-2-15 where 0.9 inch was used because it was the maximum deflection. The deflection reading of 1.0 inch was chosen arbitrarily.

Deflection measurements under the wheel relative to the number of passes of the loaded wheel are shown in Figure 32. Included in this figure are the measurements for FOMAT panels CL-2-15, CL-2-20, and S-2-20. Deflection measurements for the remaining FOMAT panels were not included in Figure 32 because only a maximum of four passes were made on these panels.

Although cross section and profile measurements were made, the results are not included herein because these may be misleading. Since the FOMAT surface rebounded from the underlying soil after passage of the wheel, the permanent unloaded deformation of the FOMAT surface was always considerably less than deflection measurements made on the same surface under load. Thus, deflection measurements represented the behavior of the surface more accurately than cross section and profile measurements.

After the traffic tests were completed, FOMAT specimens to be used in beam tests were cut out from each test panel from areas as distant as possible from the path traversed by the wheel. These specimens were cut into beams 2-inches wide and approximately 24 inches long. Their depth varied from a nominal 2-1/2 inches, depending on the amount of resin saturated soil attached to the bottom of the beam test specimens. These beams were tested under the following conditions:

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*About 1 foot.

Span	20.5 inches (simply supported)
Load	Point load at midspan
Loading Rate	0.30 in./min

The average ultimate loads obtained under these conditions for each beam specimen are reported in Table 7 under the column titled "Field Samples." Bond separation between the outer FRP layer and the inner foam core prevented testing of specimens from panels S-1-20, S-2-15, and S-2-20. Also reported in the above table are results from beam tests performed on similar specimens constructed under laboratory conditions at CEL and WES. It should be noted that beam strength is somewhat related to soil type; possibly, permeability and water content properties of the soil tended to influence the bondings of the lower FRP layer.

After traffic tests were completed, sections were cut out to permit inspection of the cross section of each FOMAT panel beneath the path of the wheel. Cuts were made transverse to the path of the wheel at 2 feet onto each panel (middle of foam billet). The cross sections of the panels are shown in Figures 33 through 40. The centerline of the path of the wheel corresponds with the white line directly beneath the centerline symbol on the reference scale shown in each figure.

DISCUSSION

Preliminary analysis using a finite element computer code indicated that FOMAT showed promise as an expedient surfacing. Subsequently, laboratory experiments performed with 2-inch-thick 20-pcf foam sandwiched between two 1/4-inch FRP faces showed that FOMAT adequately withstood various simulated F4 aircraft tests. Laboratory test panels were successfully tested against effects of jet engine heat-blast, F4 aircraft hook impact, and static F4 aircraft wheel loading on weak subgrade soil simulated in a mechanical subgrade. Field installation of test panels and traffic testing of FOMAT was therefore pursued.

Performance of the FOMAT panels in the traffic tests was less than expected. Possible reasons for the resulting difference in performance from projected laboratory results may be because of: (1) inconsistencies in spraying of the resin, (2) differences in material properties, (3) differences in construction procedures, (4) defects in the constructed panels, (5) too low strengths of the supporting soils, and (6) possibly FOMAT strength inherently too weak for the load.

Tests of 4-foot-square FOMAT (2-inch, 20-pcf foam core) in the CEL model subgrade showed that plate bearing loads of 71,750 pounds distributed over a 12-inch-diameter plate on a simulated soil with subgrade modulus of 155 pci (4-13 CBR) [9] was attainable on 2-inch 20-pcf foam core FOMAT. The F4 aircraft wheel loading used on the FOMAT panels was 30,000 pounds distributed over approximately the same area as a 12-inch-

diameter plate. Thus, the simulated F4 wheel load was less than one-half the load withstood by the laboratory specimens. The factors due to dynamic loading and edge effect on FOMAT panel performance, however, are not known. The speed of travel of the wheel over each panel averaged about 2 miles per hour. Edge effects due to the proximity of the wheel to the boundaries of the FOMAT panel as the wheel goes on and comes off each panel possibly had more significant effect on each panel than dynamic effects of the wheel.

As can be seen in Figures 33 through 40, separation of the bond between the bottom FRP layer and the foam core occurred in every panel. Some separation of the top FRP layer occurred in panels CL-2-15, CH-2-20, and CL-2-20. The cause of the separation could be several or could be a combination of the reasons for the difference in performance in the field- and laboratory-constructed FOMAT specimens. These separations, however, destroyed the load distribution capability of each panel and were the cause of premature termination of the tests. Further discussion on each of the reasons and possible correlation with the bond separation follow.

Spraying

Inconsistencies in spraying the resin may be responsible for some of the FRP/foam separations. Inconsistencies occurred on the following FOMAT panels:

Panels	Separation Location	Bottom Layer	Top Layer
CH-2-15	Bottom	Catalyst pump problem	
CH-2-20	Bottom and top	Spraying interrupted for resin resupply	
CH-1-20	Bottom		Catalyst pump problem
S-2-20	Bottom	Resin from different containers used to spray each layer	

Construction Materials

Some differences in the material used to construct each FOMAT panel may have been present. Variations in foam thicknesses from the nominal 1 and 2 inches and from the nominal 15- and 20-pcf unit weights may have occurred. Some variations occurred also in the thickness of the outer FRP layer of each panel. It is believed that these variations, however, have only a minor (if any) effect on the resulting performances of each panel.

Construction Procedures

The differences in the construction procedure used in constructing the field FOMAT panels and the construction procedures used for the laboratory specimens probably had significant effects on performance. The laboratory specimens were constructed with the fiberglass laid on top of the foam core. Through gravity and fiberglass rolling, the applied resin permeated through the glass and into the accessible open pores of the foam. The benefits of gravity permeation of resin into the open pores of the foam core and the increases in FRP strength due to rolling of the fiberglass were not available for the bottom faces of the field-constructed FOMAT. In the field FOMAT panels, the foam core was placed on top of the fiberglass matting which had a thin layer of excess resin on it. It is believed that entrapped air (or gas generated during resin curing) in the exposed surface pores of the foam prevented the resin from entering the open pores, thereby resulting in a weak bond at the bottom FRP/foam core interface.

Construction Defects

Visual inspection of the completed FOMAT panels revealed that the top FRP of panel S-1-20 was not bonded on about one-third of the traffic side. Repair of the bond was made with hand-mixed resin. This repair procedure was effective as evidenced by the absence of bond separation of the repaired upper FRP/foam interface (Figure 34).

Other defects noted during inspection included gas bubbles trapped beneath the FRP on all panels. Such bubbles were especially prevalent on CL-2-15 which separated at the upper FRP/foam interface (Figure 36). Since the bottom FRP/foam interface was not visible on any of the panels after construction, the occurrence of any defects at this interface is not known.

Supporting Subsoils

The strength of the supporting soils beneath some of the field FOMAT panels was less than that simulated in the CEL model subgrade during the tests of laboratory samples. The subgrade modulus in the laboratory tests was 155 psi/in., which compares with that for the soils in each field test pit (Table 8). Although subgrade modulus is usually determined from results of tests with a 30-inch-diameter plate, the results as shown for tests with a 12-inch-diameter plate provide a basis for comparison of subgrade supporting capability [10]. Table 8 shows that all of the heavy clay soils had subgrade moduli that were less than those simulated in the laboratory tests. The lean clay and sand soils in the remaining test pits all possessed subgrade moduli that were higher than the 155 psi/in. simulated in the laboratory. It is possible that excessive displacement resulting from failure of the weaker heavy clay soils beneath each FOMAT panel were precursors to bond failure at the FRP/foam interface. However, it is also possible that because of

existing separations, the FOMAT panels could not support and distribute the applied wheel loading, thereby causing excessive displacements of the underlying subgrade soils. Nevertheless, the weak soils were a contributing factor to early termination of the tests.

FOMAT Capacity

To determine if the cause of the bond separation was due to the FOMAT being inherently too weak to support the loading, the finite element computer analysis used earlier in the developmental program was refined to reflect actual conditions for soil surfacings [5]. The conditions assumed were as follows: (1) the surfacing had a finite width (radius) of 8 load-area radii*, with the outer boundary free to move in any direction; (2) the soil involved in the interaction was a cone frustum of 8-radii width at the top with sides sloping outward at 30 degrees from the vertical and a frustum height of 15 radii; (3) the outer boundary of the cone was free to move vertically but restrained horizontally; and (4) the loading was 250 psi. The results of this analysis are compared with ultimate strength values of the material and are shown in Table 9. In the majority of the cases, the calculated deflections agreed closely with those based on extrapolation or interpolation of deflections measured in plate bearing tests on the actual FOMAT panels just prior to traffic testing. At the corresponding calculated deflections, the maximum calculated stresses were compared with the ultimate strength of the foam core material. This comparison showed that in all cases, the ultimate strength was higher by a factor of 1.5 or more than the calculated maximum stresses. It can, therefore, be concluded that the bonding failures which occurred in the field-fabricated FOMAT panels were not due to inherent weakness of the basic component materials.

FINDINGS

1. Analytical and laboratory investigations have shown that FOMAT structural soil surfacing, consisting of a rigid polyurethane foam core sandwiched between two fiberglass reinforced plastic (FRP) layers, has good potential as an expedient surfacing. Finite element computer analyses have shown that 15- and 20-pcf foam core between two nominally 1/4-inch-thick exterior layers can support F4 aircraft wheel loadings of 30,000 pounds with a good margin of safety (1.5 and higher). Laboratory tests of FOMAT panels under static plate loadings in a mechanical simulated subgrade confirmed the load carrying capability of FOMAT as determined in the analyses. Additional laboratory tests showed that FOMAT meets or exceeds F4 aircraft arresting gear hook impact and jet engine heat/blast performance specifications as a heavy-duty matting.

*1 radius is the width of the area on which the load is applied and equalled 6.18 inches in this case.

2. Field fabrication of FOMAT panels showed that a problem exists with bonding of the polyurethane foam core and the bottom FRP layers. All of the eight field-fabricated panels experienced some bond separation between these layers. The reasons for the separations possibly may be (1) inconsistencies in spraying of the resin, (2) deficiencies in construction procedures, (3) weak supporting soils, and (4) previously-existing defects in the constructed panels. The bond separations were the cause of premature termination of the traffic tests.

3. Traffic tests were made with a simulated F4 aircraft wheel on eight, field-fabricated FOMAT panels each 8 by 12 feet in size. These panels were fabricated over heavy clay (2-3 CBR), lean clay (10 CBR), and sand (6-12 CBR) soils. The following numbers of passes were achieved before the FOMAT surface experienced a deflection of 0.9 to 1.0 inch under the wheel:

Soil Type	Foam Density (pcf)	Foam Thickness (in.)	No. Passes
Lean Clay	15	2	40
Lean Clay	20	2	40
Sand	20	2	22
Sand	15	2	4
Sand	20	1	4
Heavy Clay	20	2	1
Heavy Clay	15	2	1
Heavy Clay	20	1	1

From the above data it can be seen that termination of the traffic tests on each panel was dependent on the soil rather than on the FOMAT installed; thus, it is likely that deficiencies were present in the constructed panels prior to testing.

RECOMMENDATIONS

It is recommended (1) that field construction techniques be investigated to insure positive bond between the polyurethane foam core and particularly the lower (bottom) FRP layer, (2) that after development of techniques, effectiveness be verified in field construction experiments, and (3) that traffic tests be performed on the fabricated FOMAT from these experiments to obtain design data.

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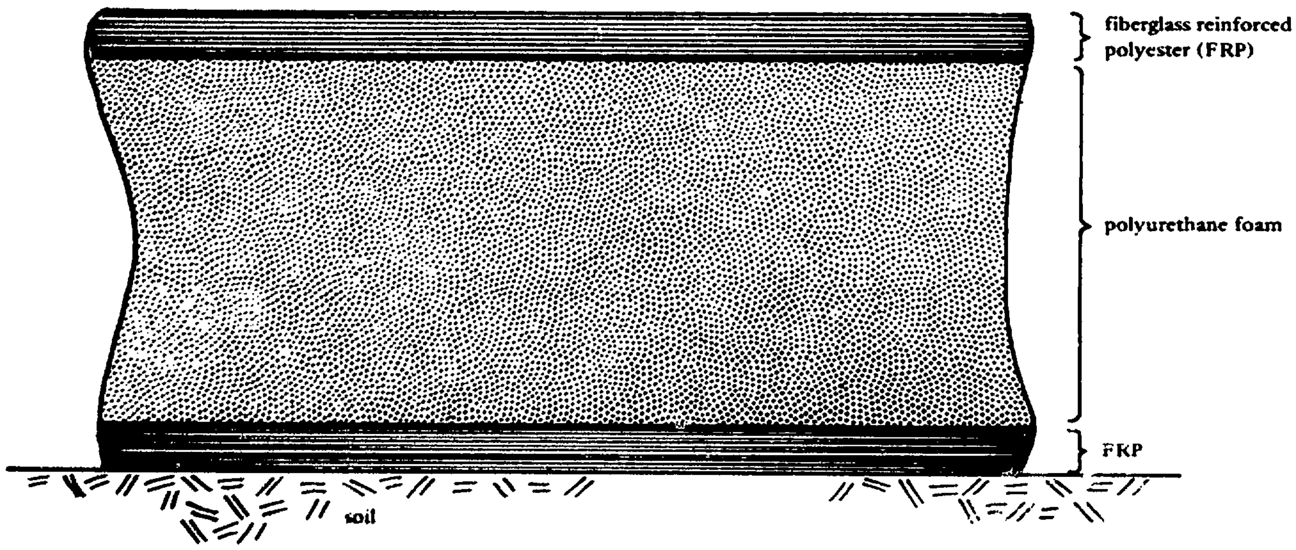

Figure 1. Typical FOMAT construction (two fiberglass mattings on each side).

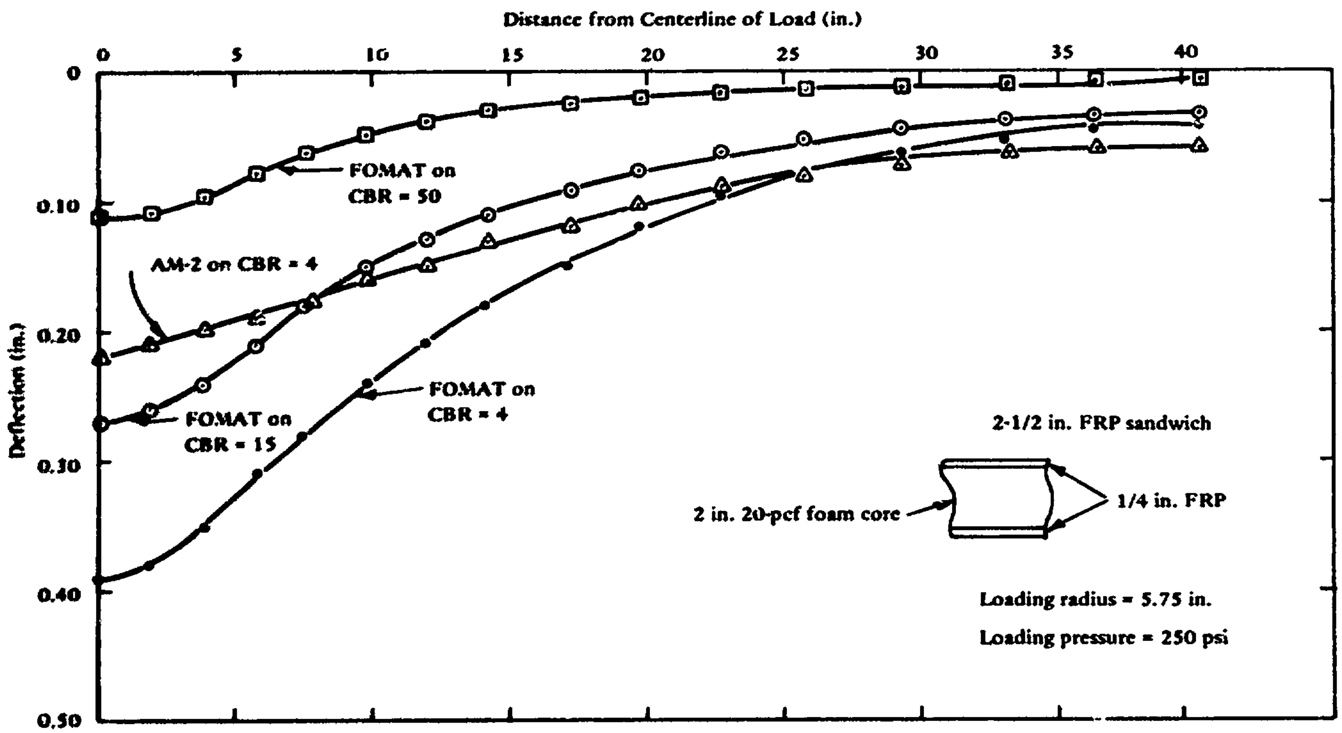

Figure 2. Surface deflection under load (20-pcf foam core) as computed in finite element analysis.

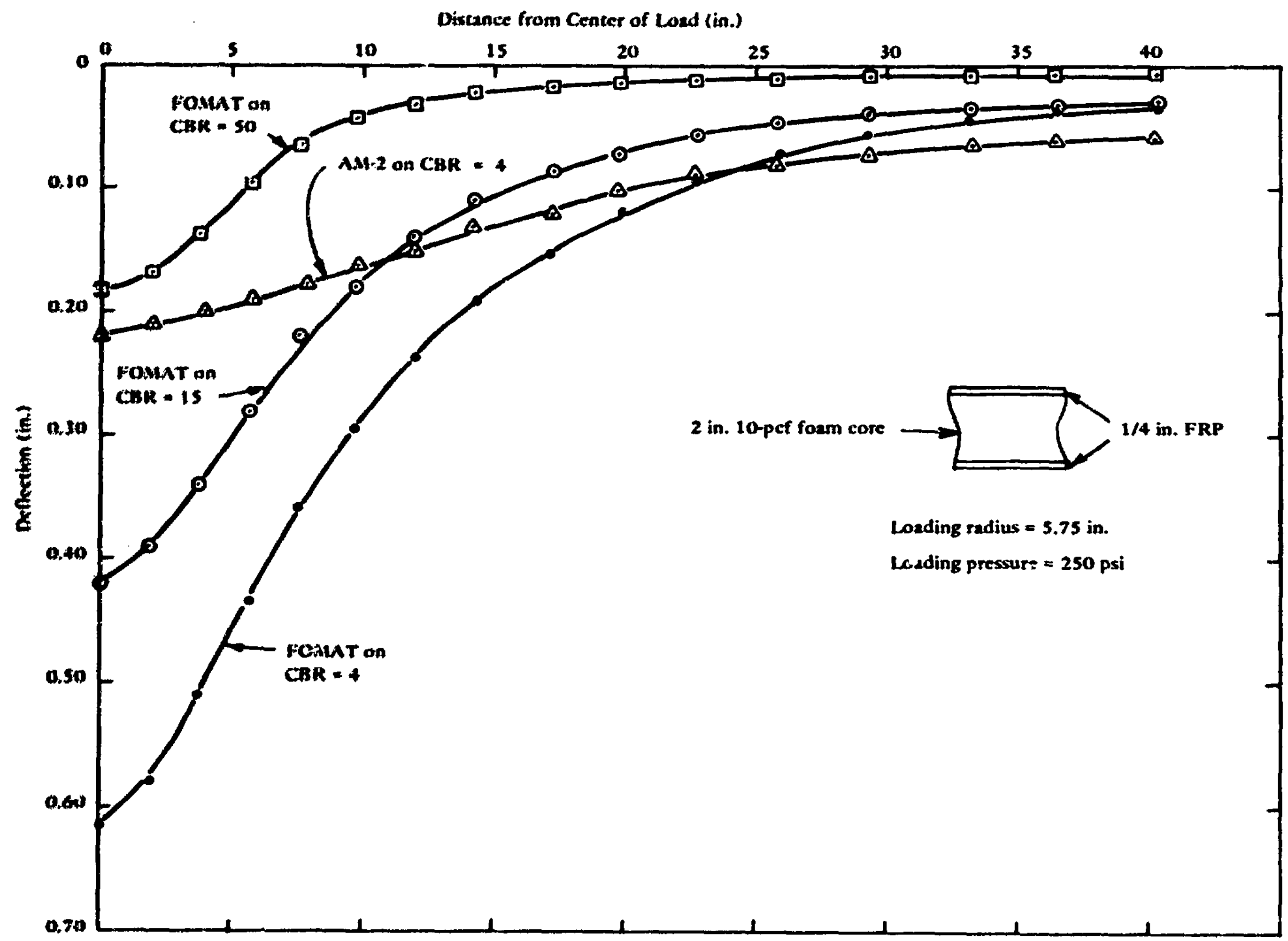

Figure 3. Surface deflections under load (10-pcf foam) as computed in finite element analysis.

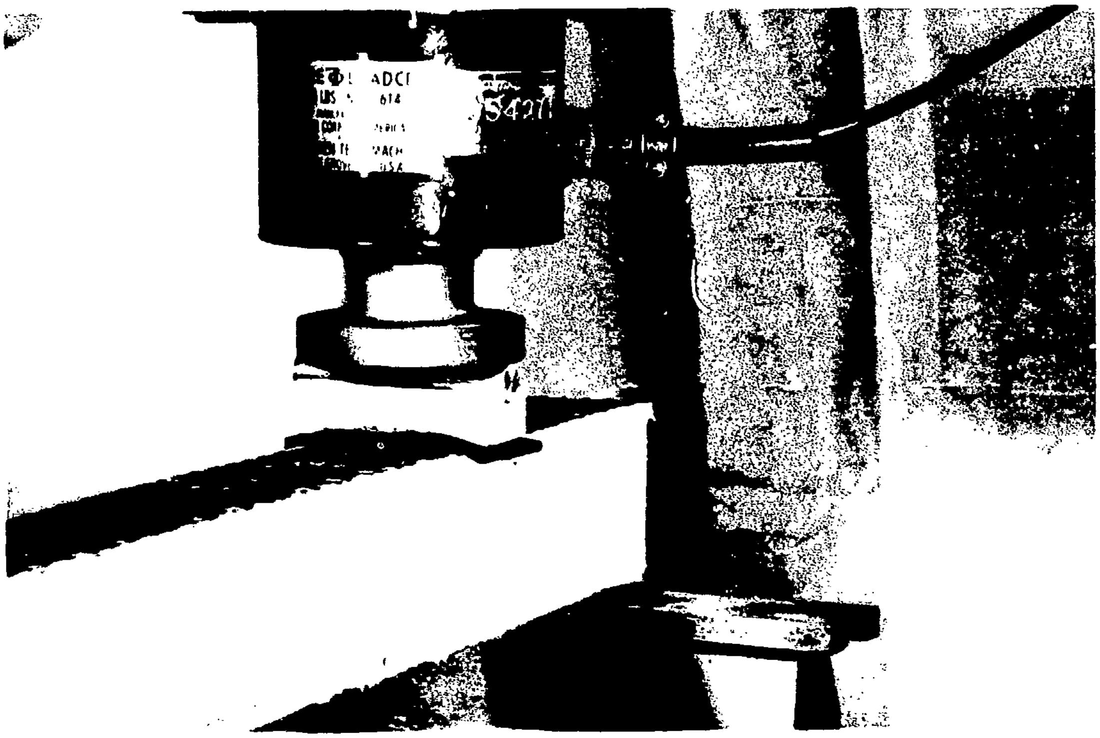

Figure 4. Flexural load test.

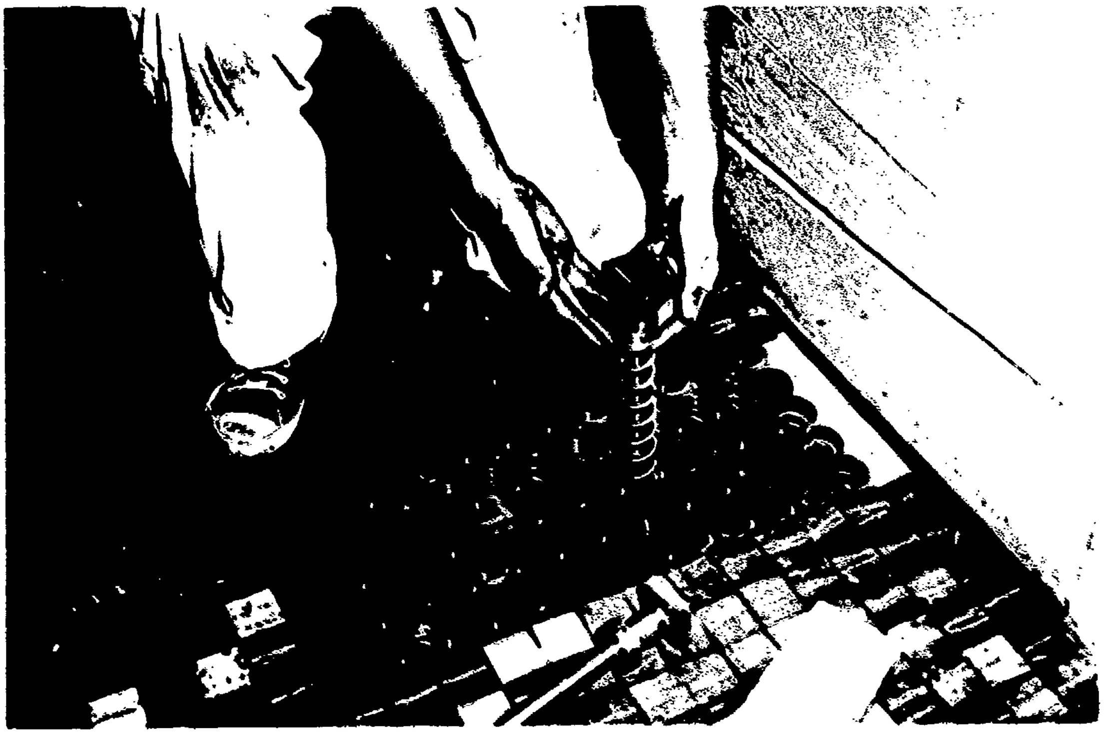

Figure 5. Mechanical subgrade.

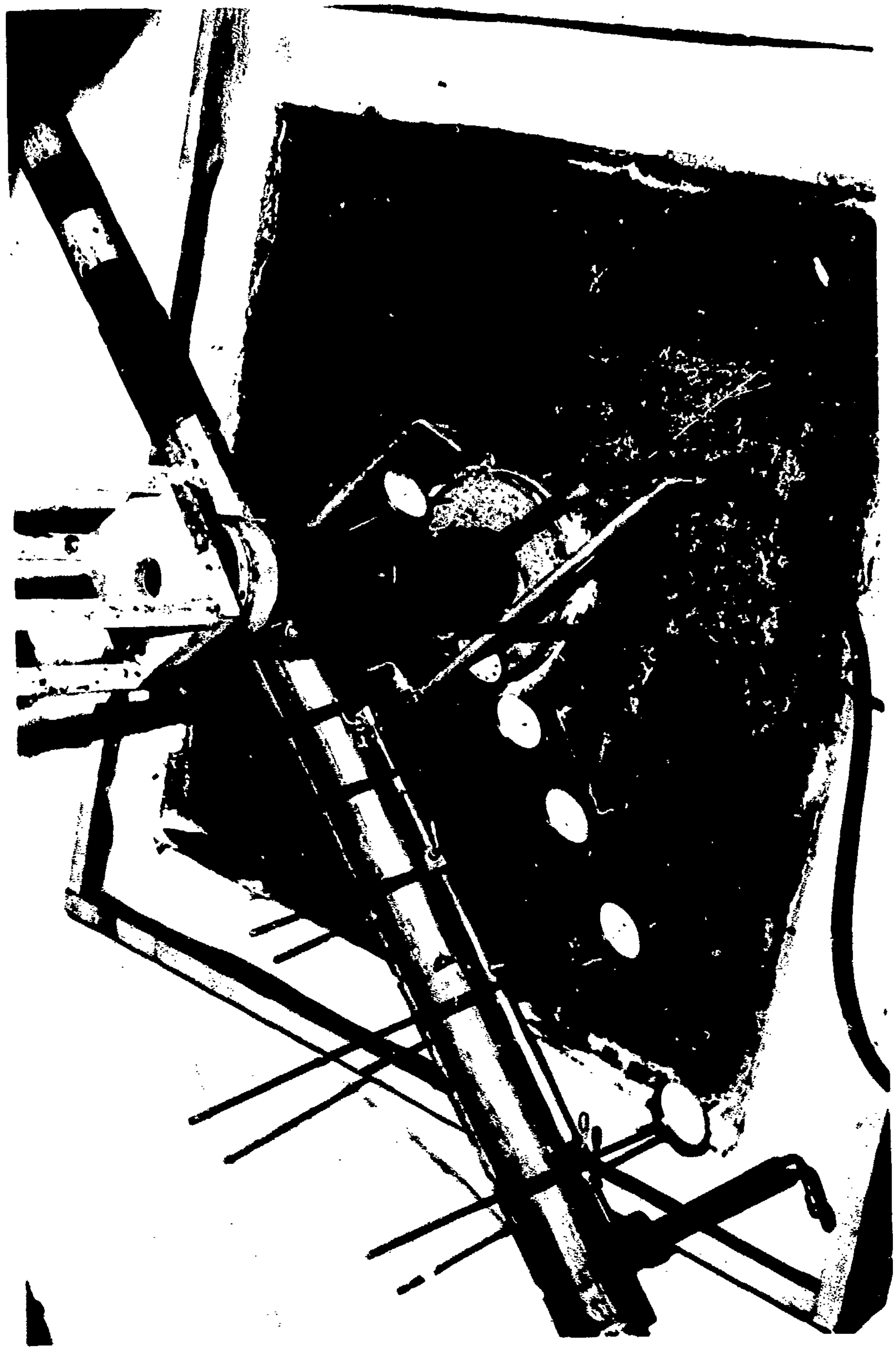

Figure 6. FOMAT load test in mechanical subgrade.

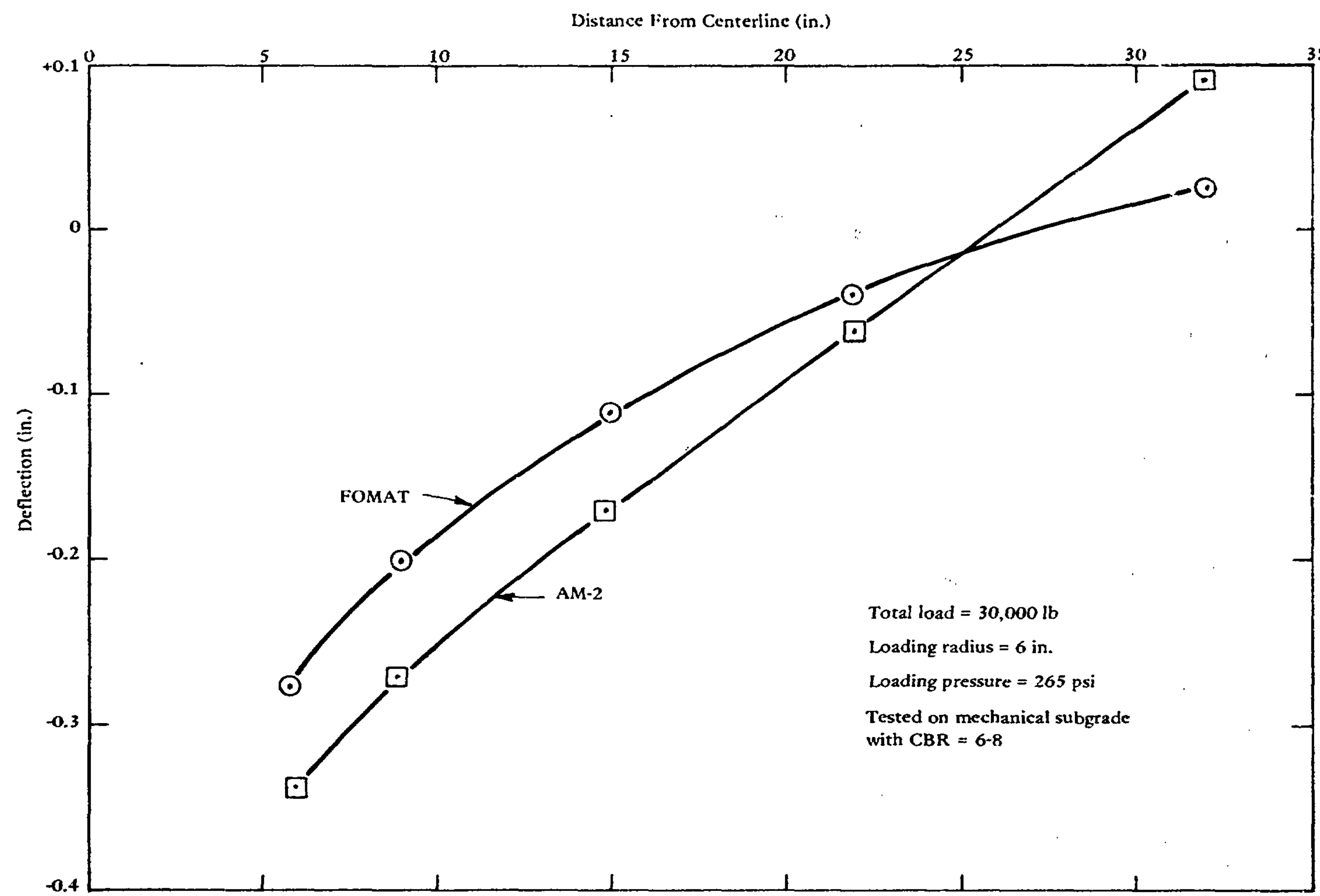

Figure 7. Surface deflection under load for FOMAT (20-pcf foam core) and AM-2 matting, as measured in tests in the mechanical subgrade.

Figure 8. Jet blast test area.

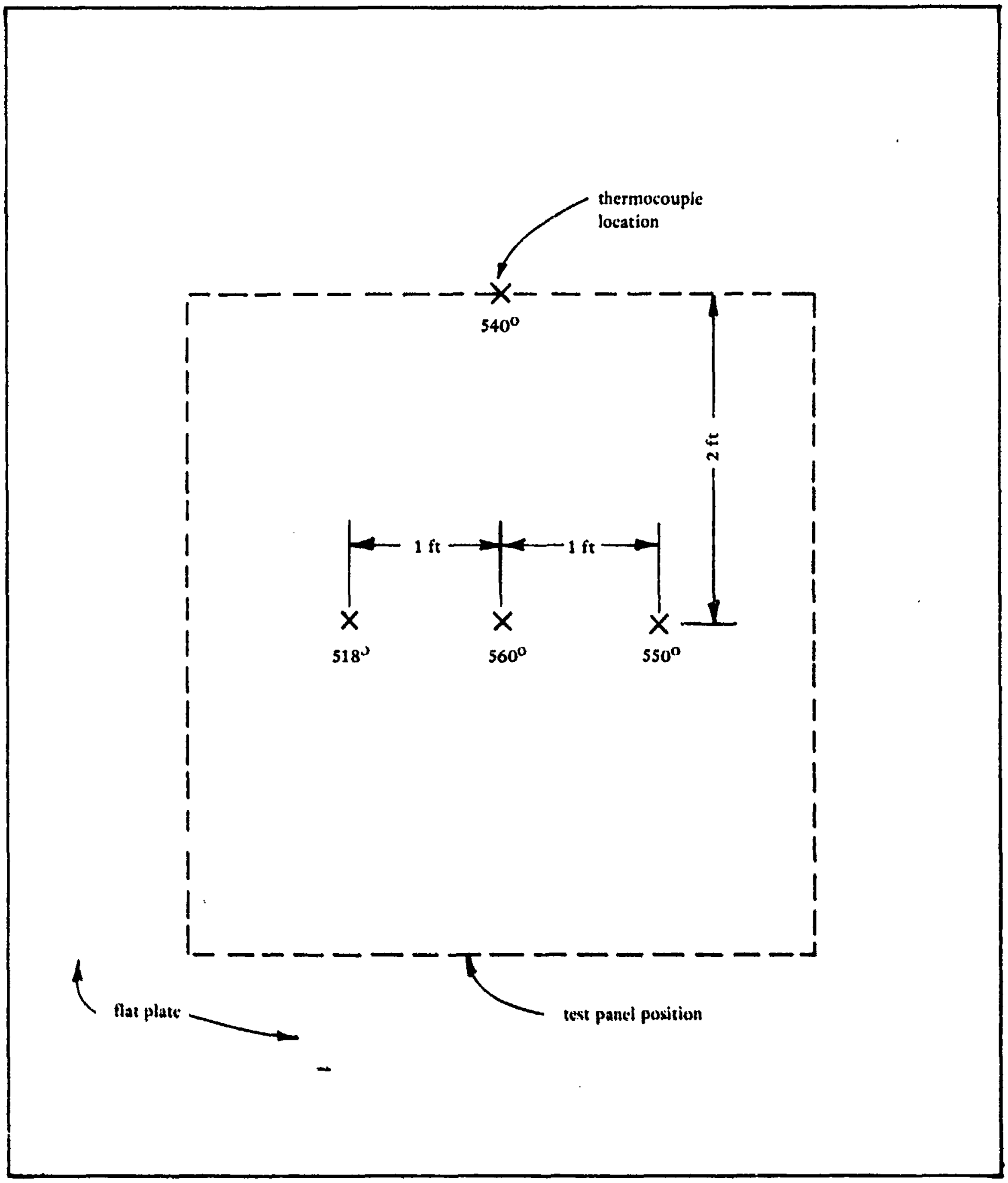

Figure 9. Thermocouple locations and temperatures measured on the test table prior to installation of the FOMAT panel for the nominal 500°F tests.

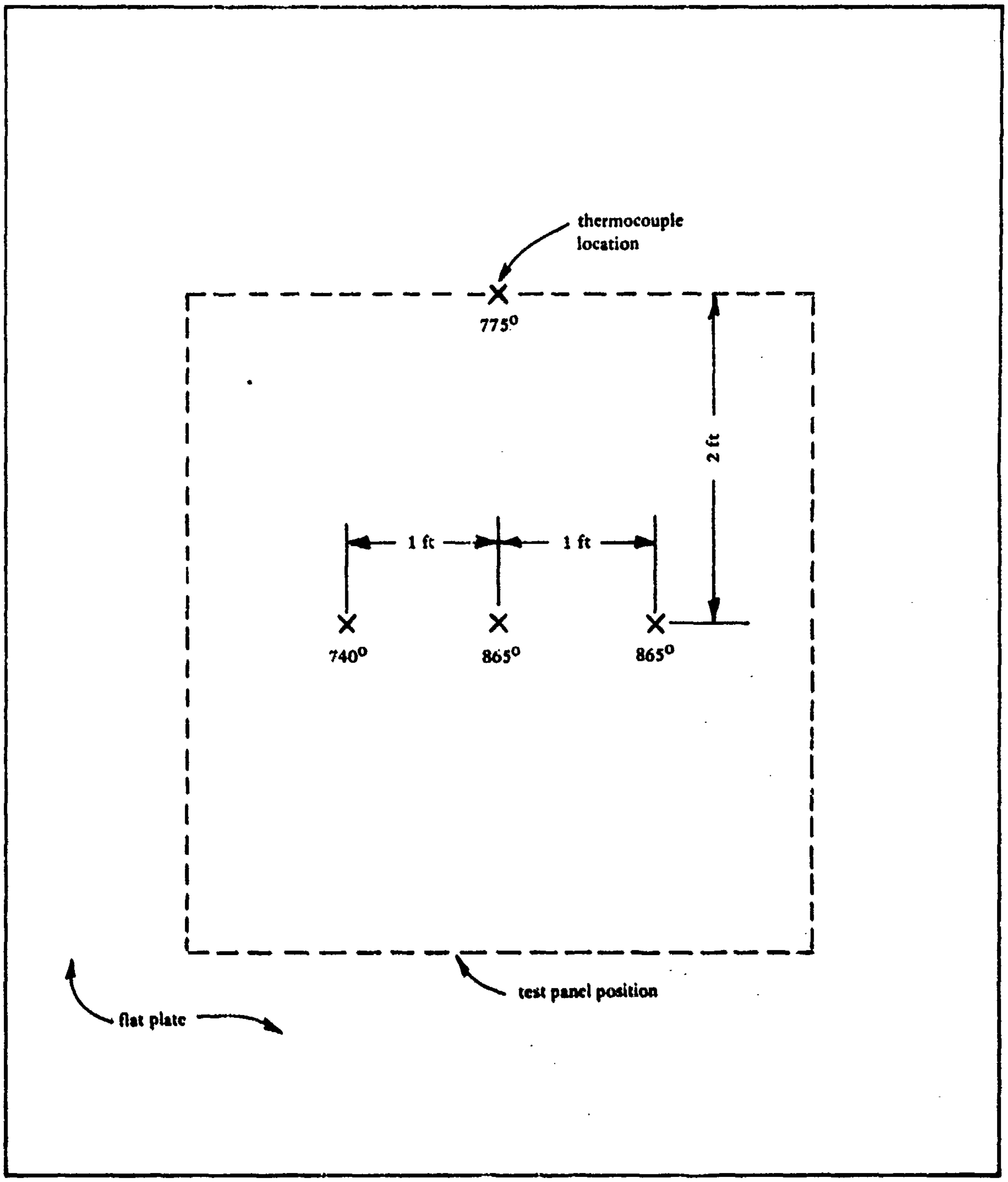

Figure 10. Thermocouple locations and temperatures measured on the test table prior to installation of the FOMAT panel for the nominal 750°F tests.

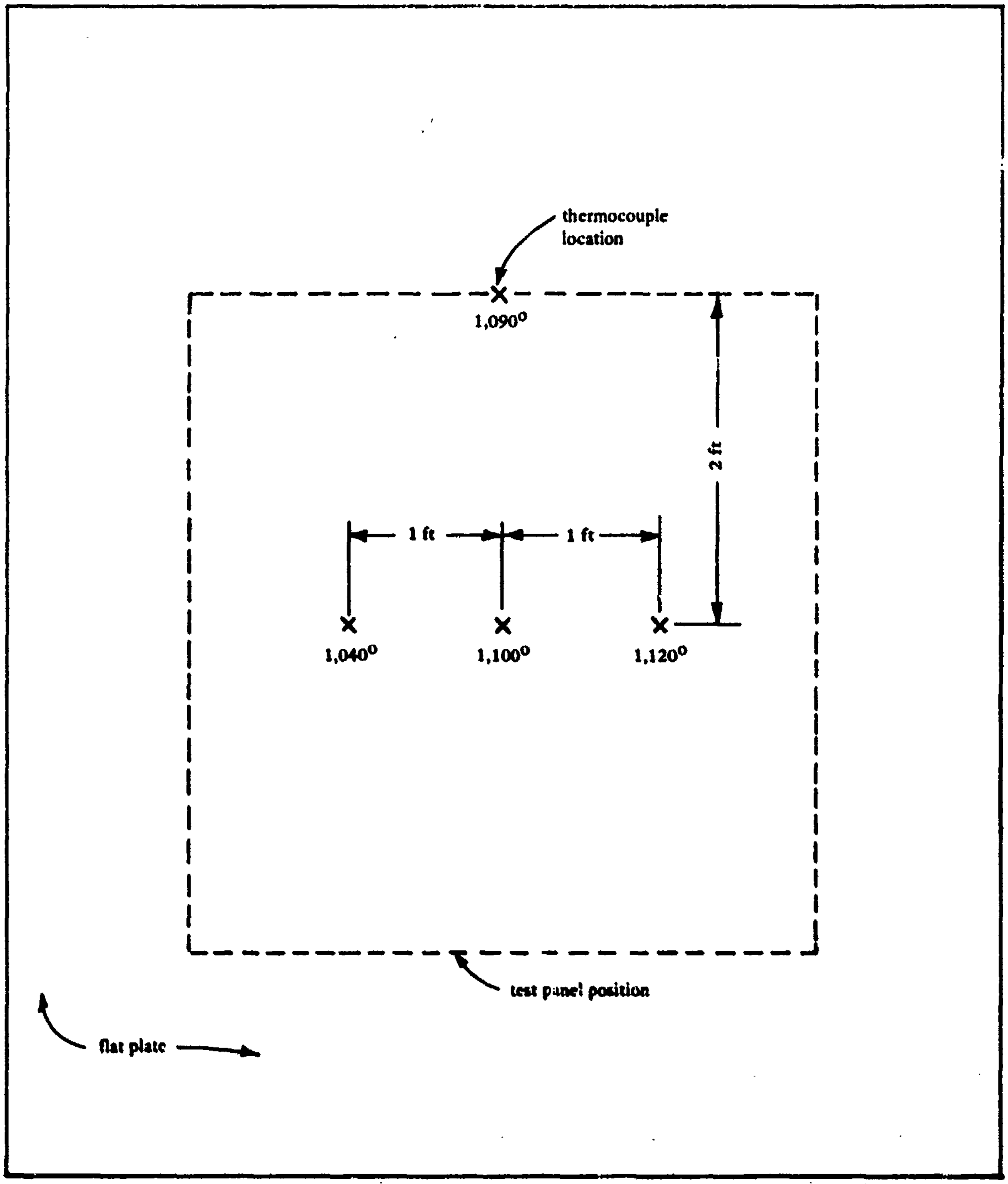

Figure 11. Thermocouple locations and temperatures measured on the test table prior to installation of the FOMAT panel for the nominal 1,000°F tests.

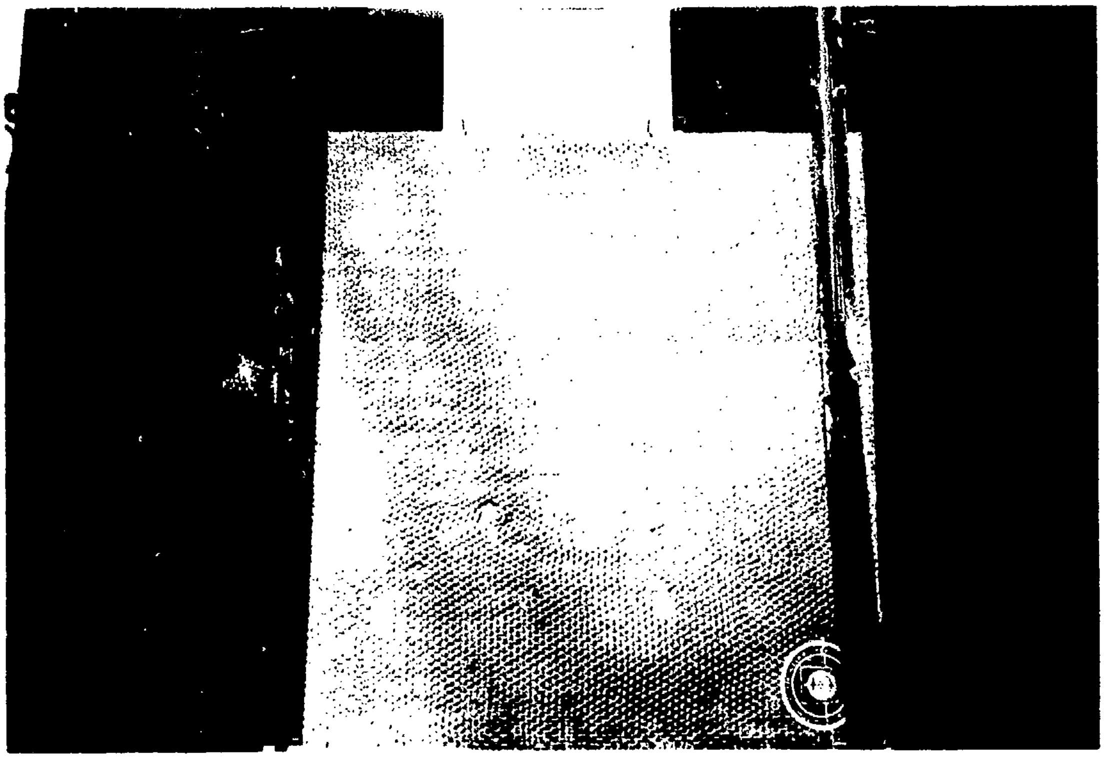

Figure 12. Panel 1 before heat/blast test.

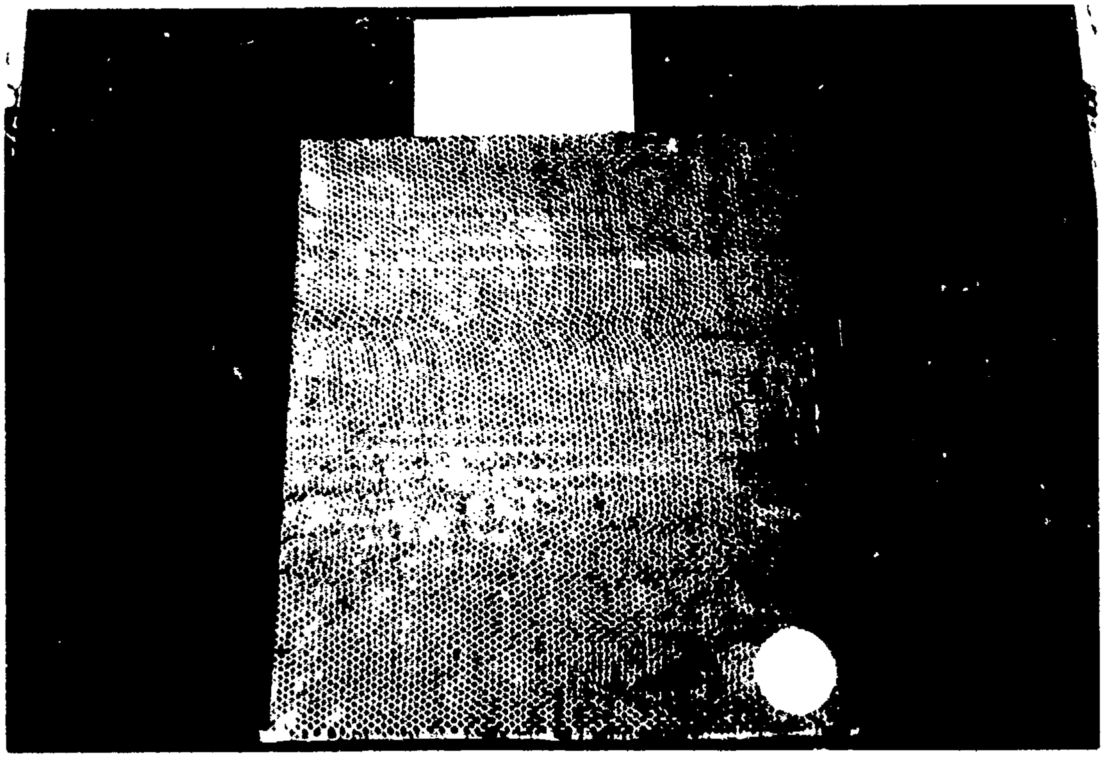

Figure 13. Panel 1 after $500^{\circ}F$ testing.

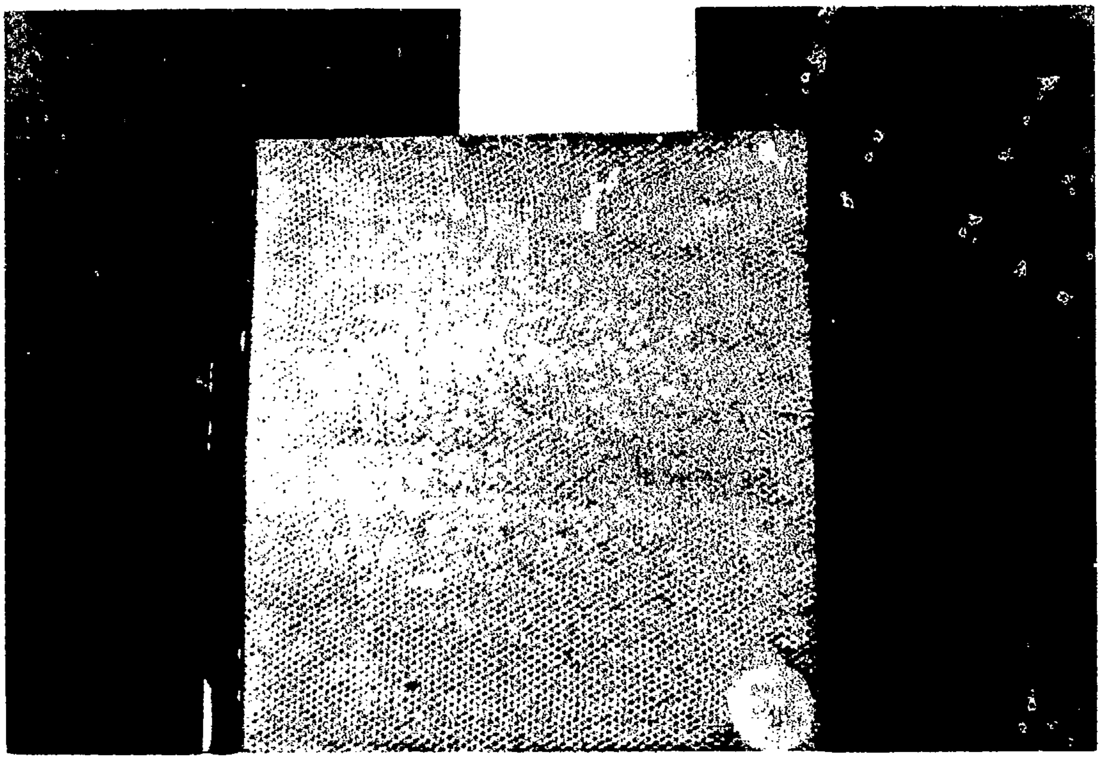

Figure 14. Panel 1 after 750°F testing.

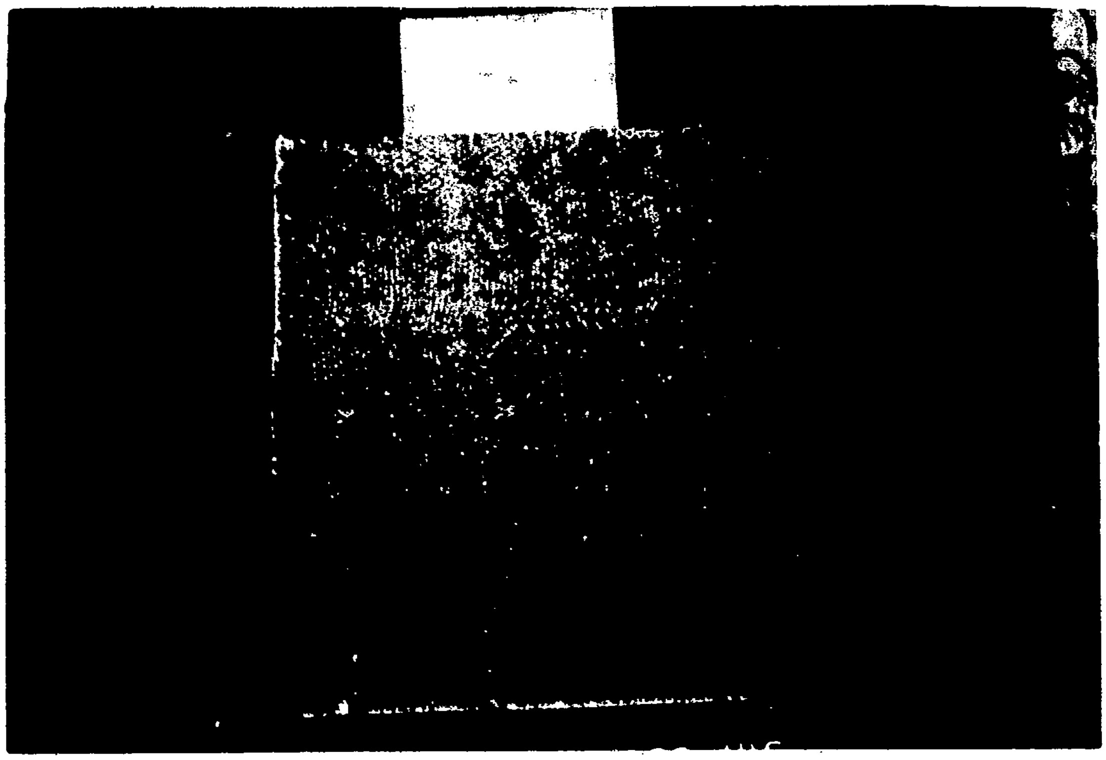

Figure 15. Panel 1 after 1,000°F testing.

Figure 16. Hook impact test facility.

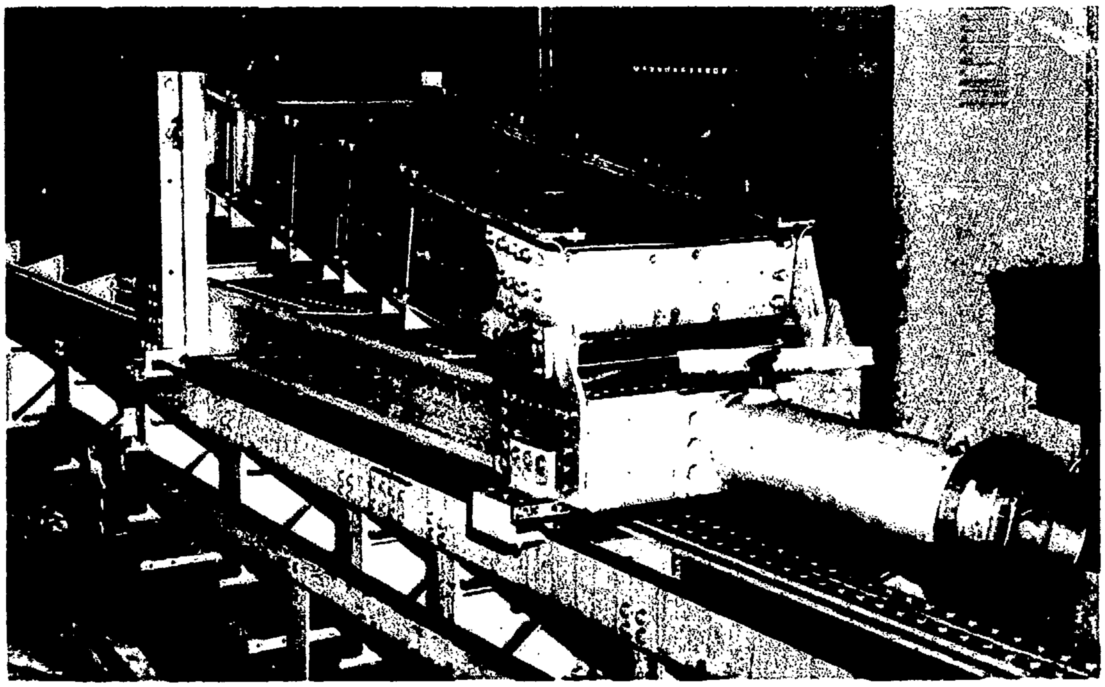

Figure 17. Catapult assembly.

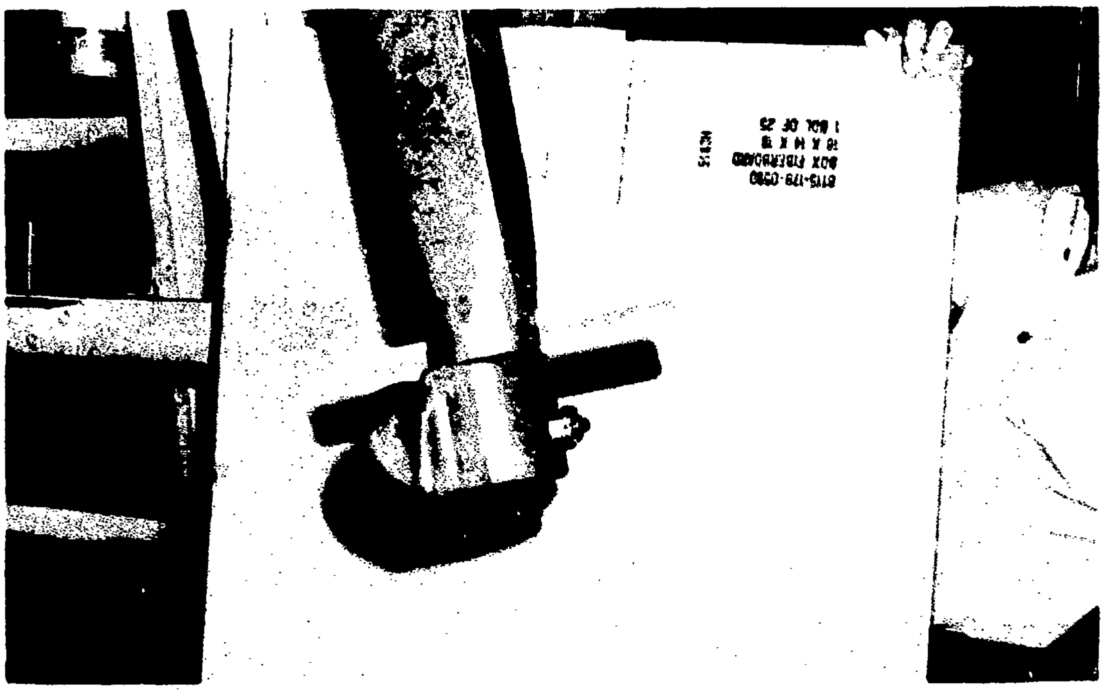

Figure 18. Arresting gear hook.

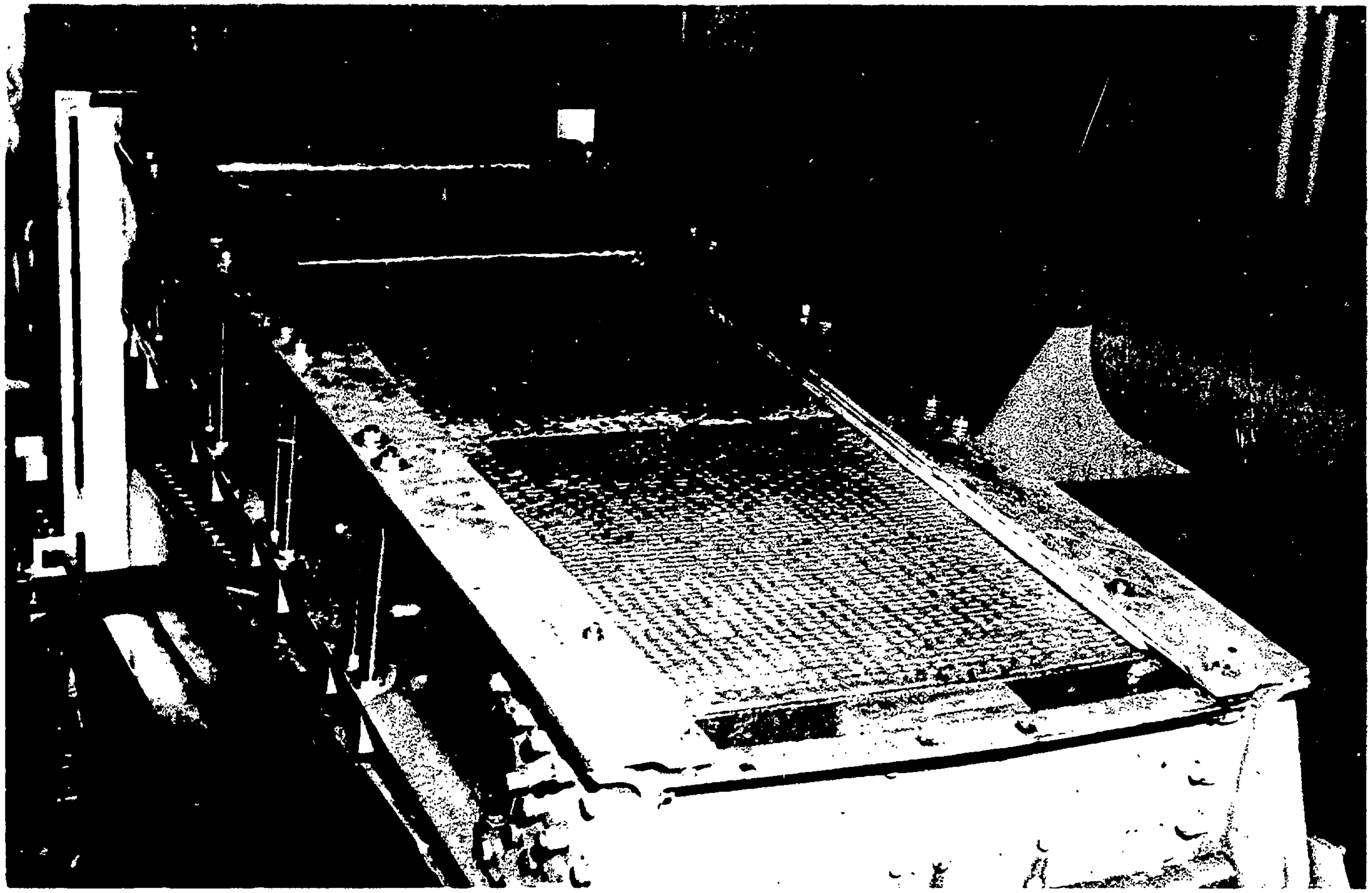

Figure 19. Panel ready for test.

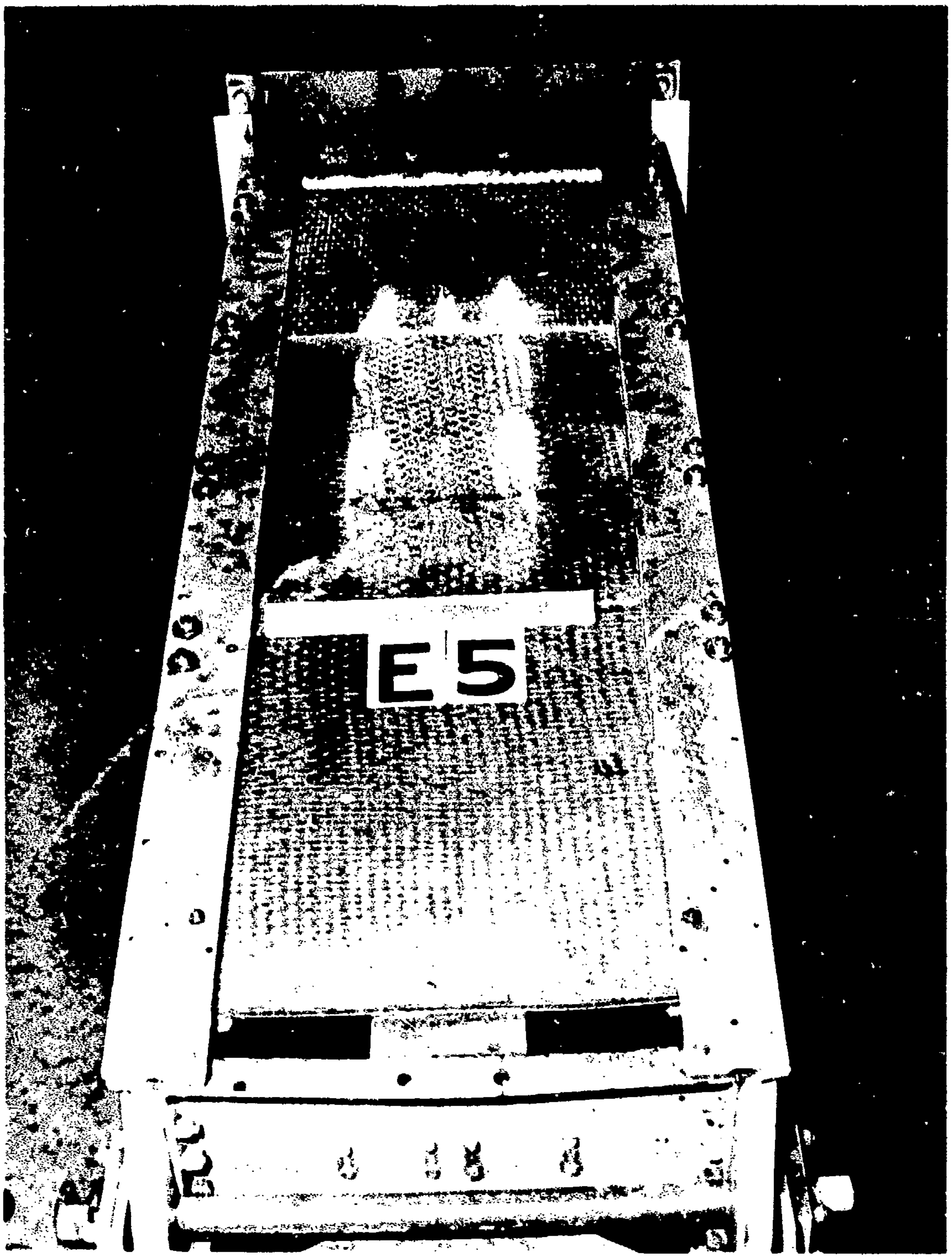

Figure 20. Panel after completion of 5 test cycles.

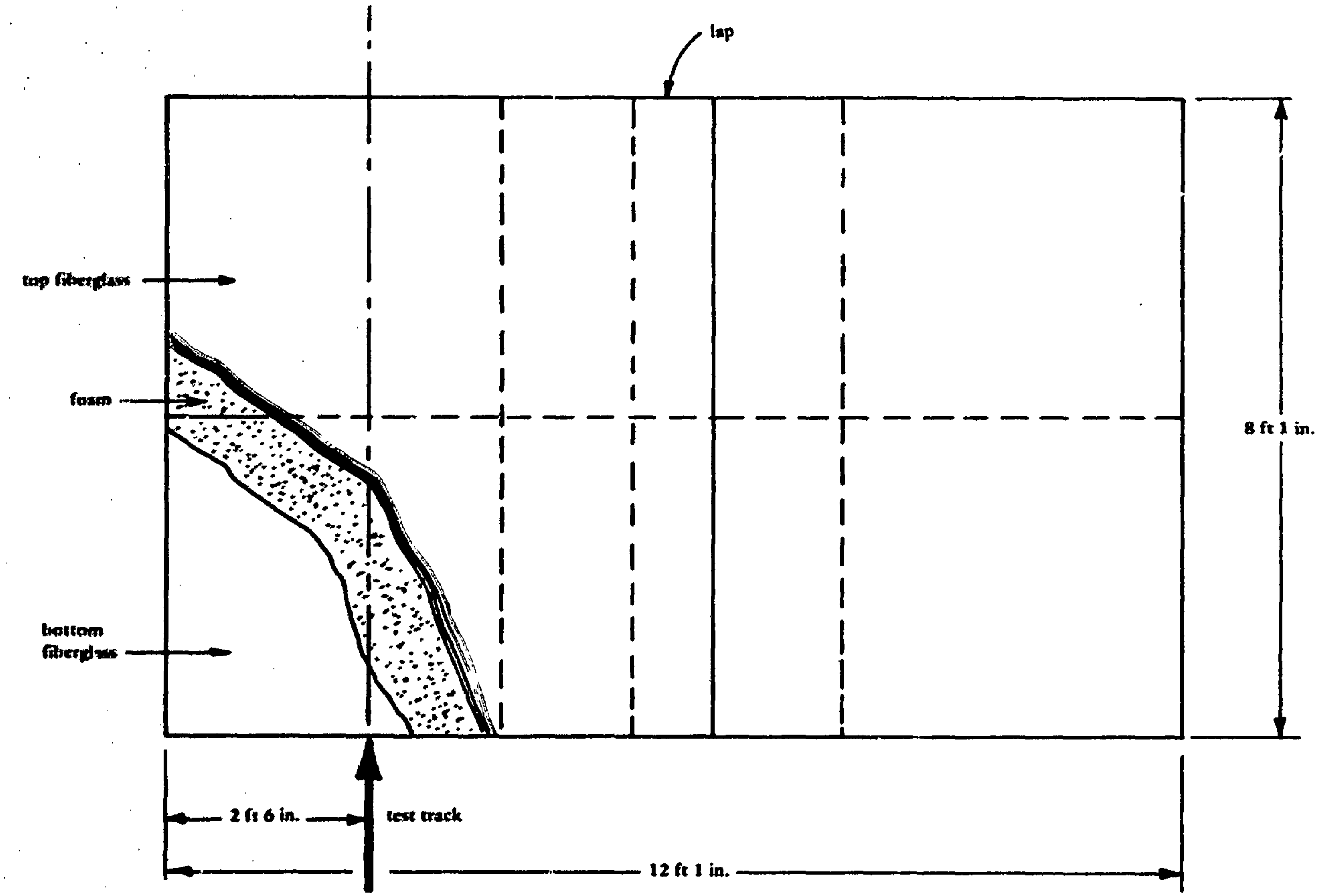

Figure 21. Typical field FOMAT test panel constructed at WES showing positions of foam billets, location of fiberglass lap joint, and location of test track.

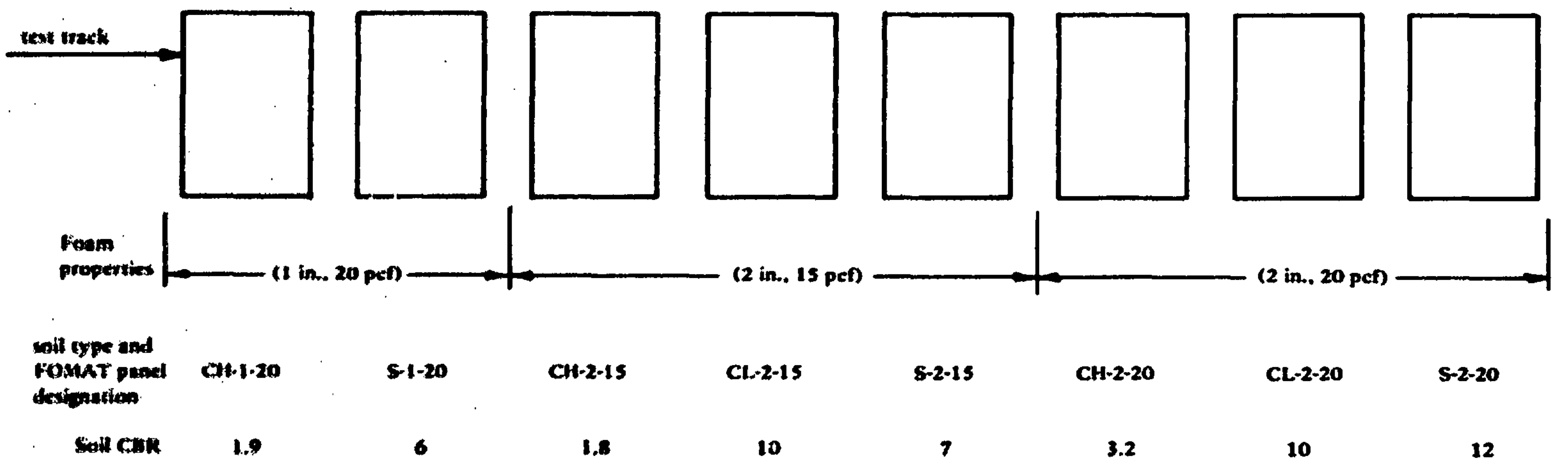

Figure 22. Location of the test track, and panel designation, along with foam properties, soil type and CBR (before traffic) of materials installed in each test pit. Soil types: CH = heavy clay; CL = lean clay; and S = sand.

Figure 23. Overall view of FOMAT test panels prior to trafficking, showing the centerline for the trafficking wheel (white line to left of center) and aluminum matting at ends and between FOMAT panels.

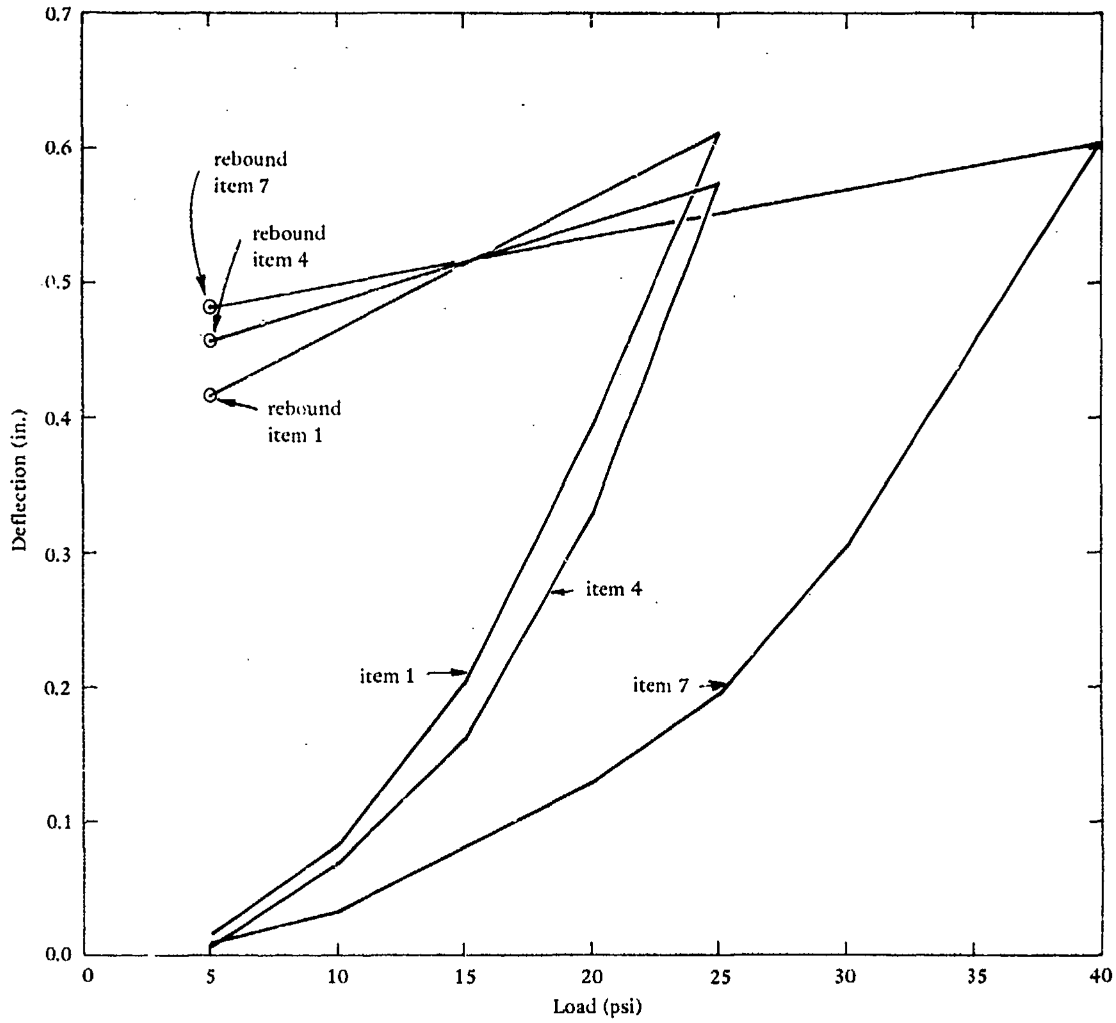

Figure 24. Plate bearing test results on surface of heavy clay soils in pits (items 1, 4, and 7 for FOMAT panels CH-1-20, CH-2-15 and CH-2-20, respectively).

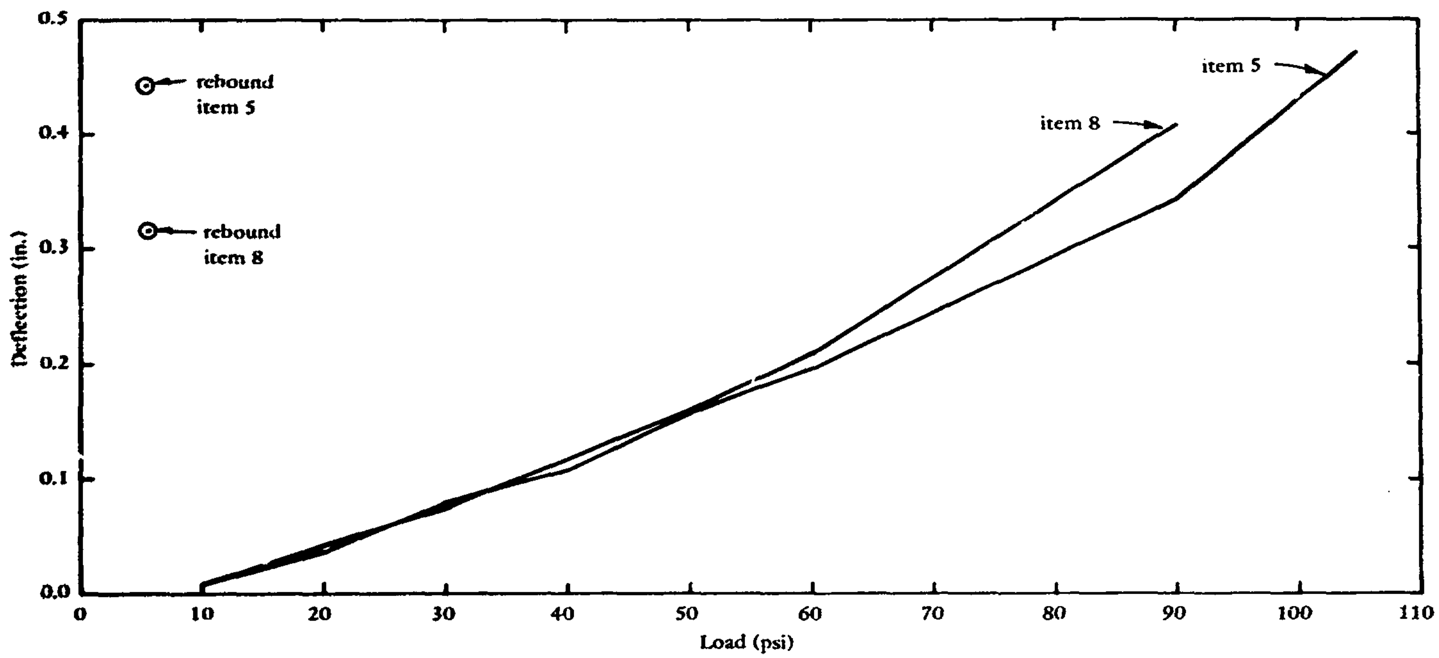

Figure 25. Plate bearing test results on surface of lean clay soils in pits (items 5 and 8 for FOMAT panels CL-2-15 and CL-2-20, respectively).

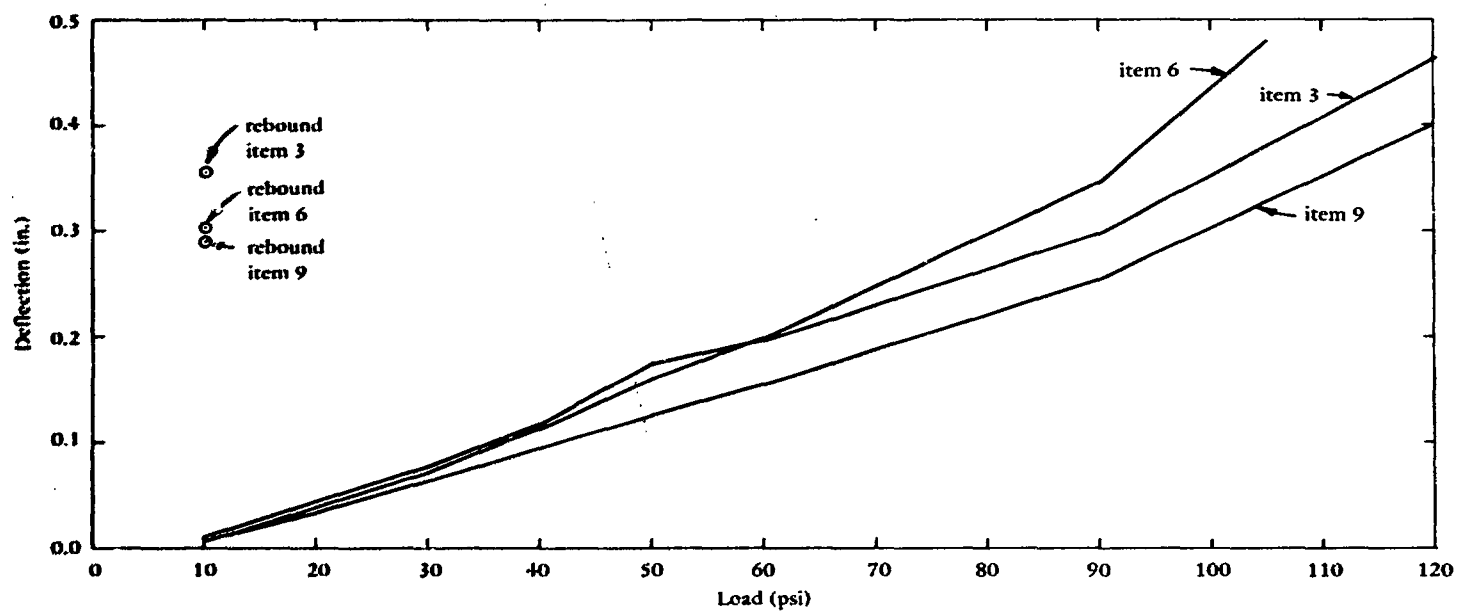

Figure 26. Plate bearing test results on surface of sand soils in pits (items 3, 6, and 9 for FOMAT panels S-1-20, S-2-15 and S-2-20, respectively).

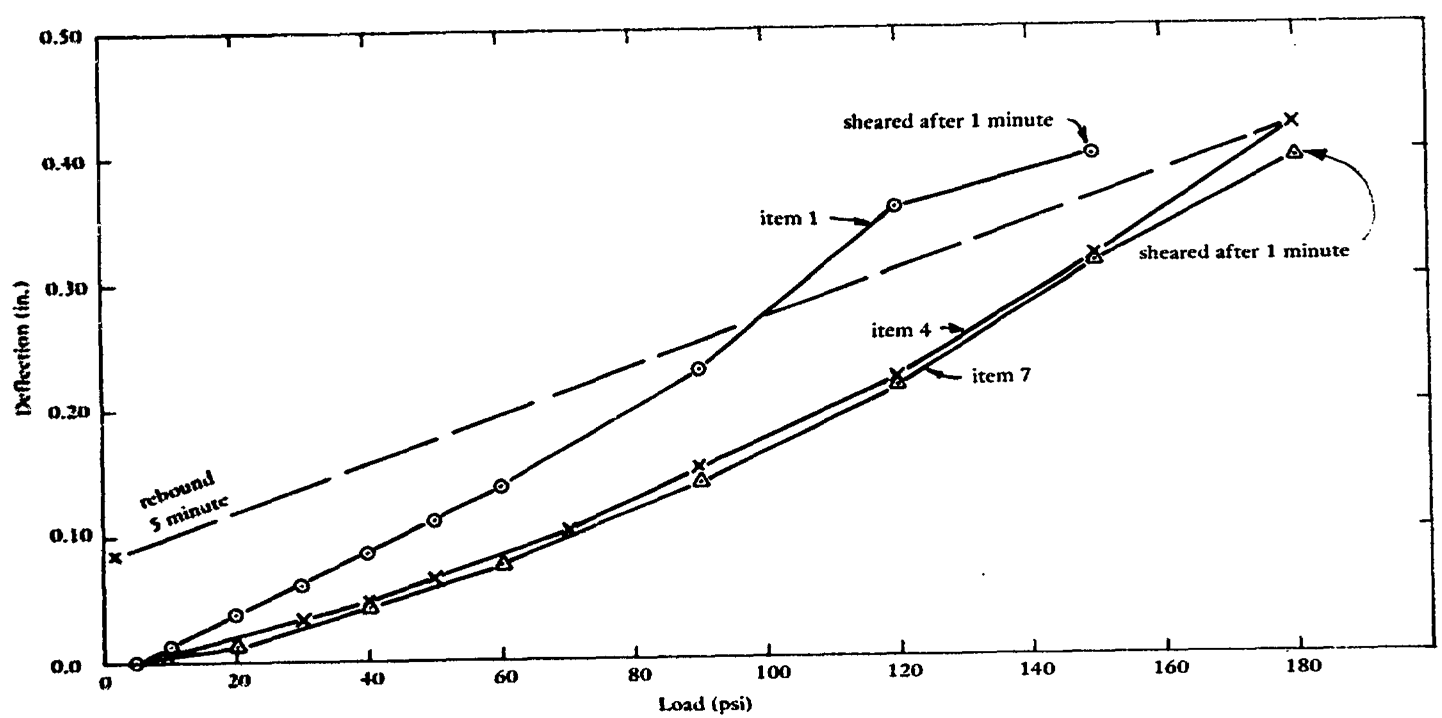

Figure 27. Plate bearing test results on surface of FOMAT panels CH-1-20, CH-2-15 and CH-2-20 (items 1, 4, and 7, respectively).

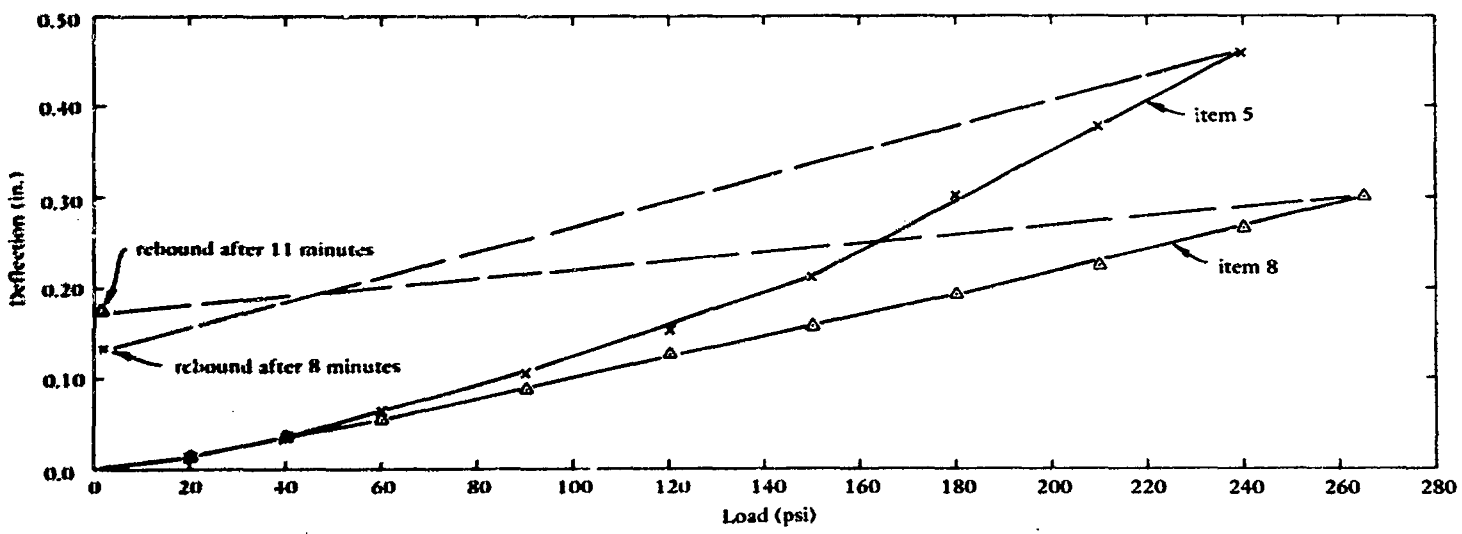

Figure 28. Plate bearing test results on surface of FOMAT panels CL-2-15 and CL-2-20 (items 5 and 8, respectively).

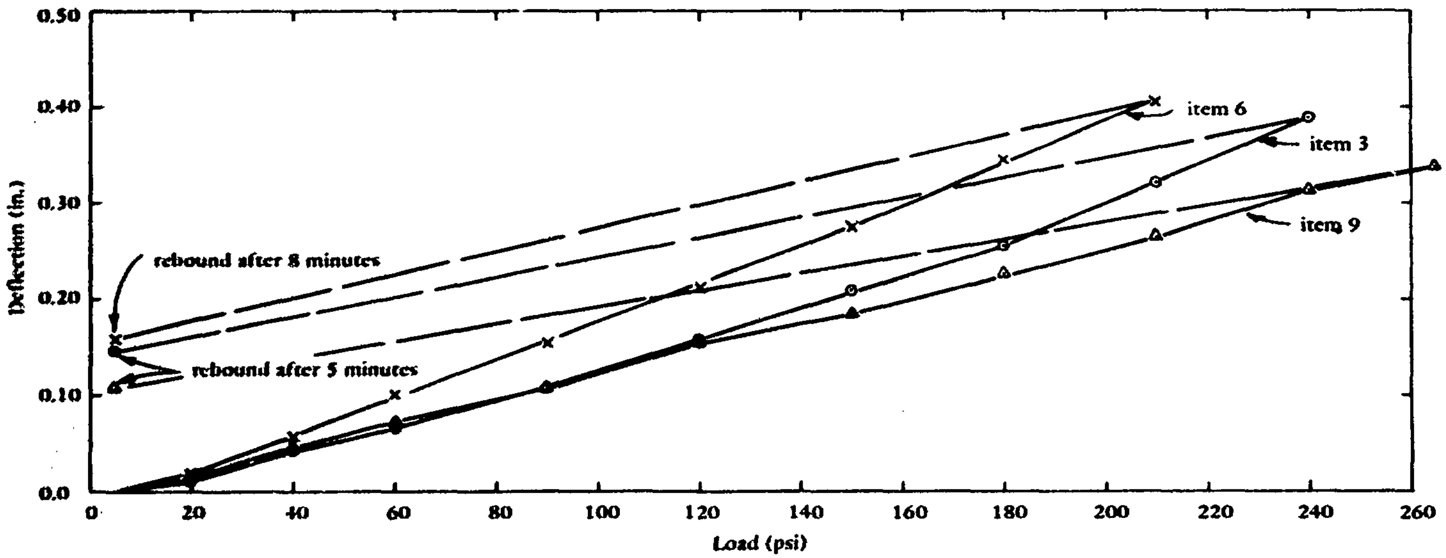

Figure 29. Plate bearing test results on surface of FOMAT panels S-1-20, S-2-15 and S-2-20 (items 3, 6, and 9, respectively).

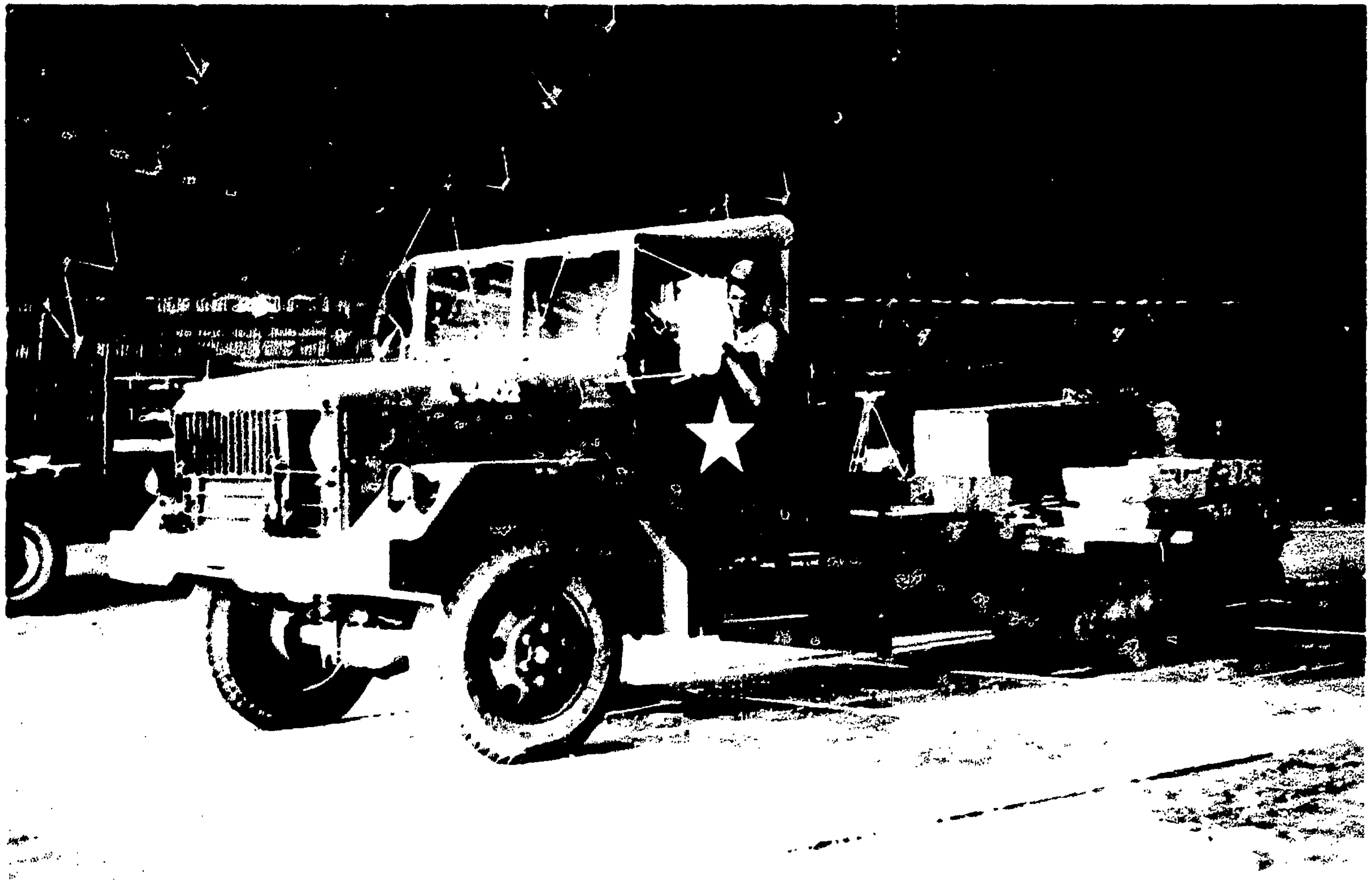

Figure 30. Vehicle with F4 aircraft wheel on rear, weighted to 30,000 pounds with lead to simulate traffic loading.

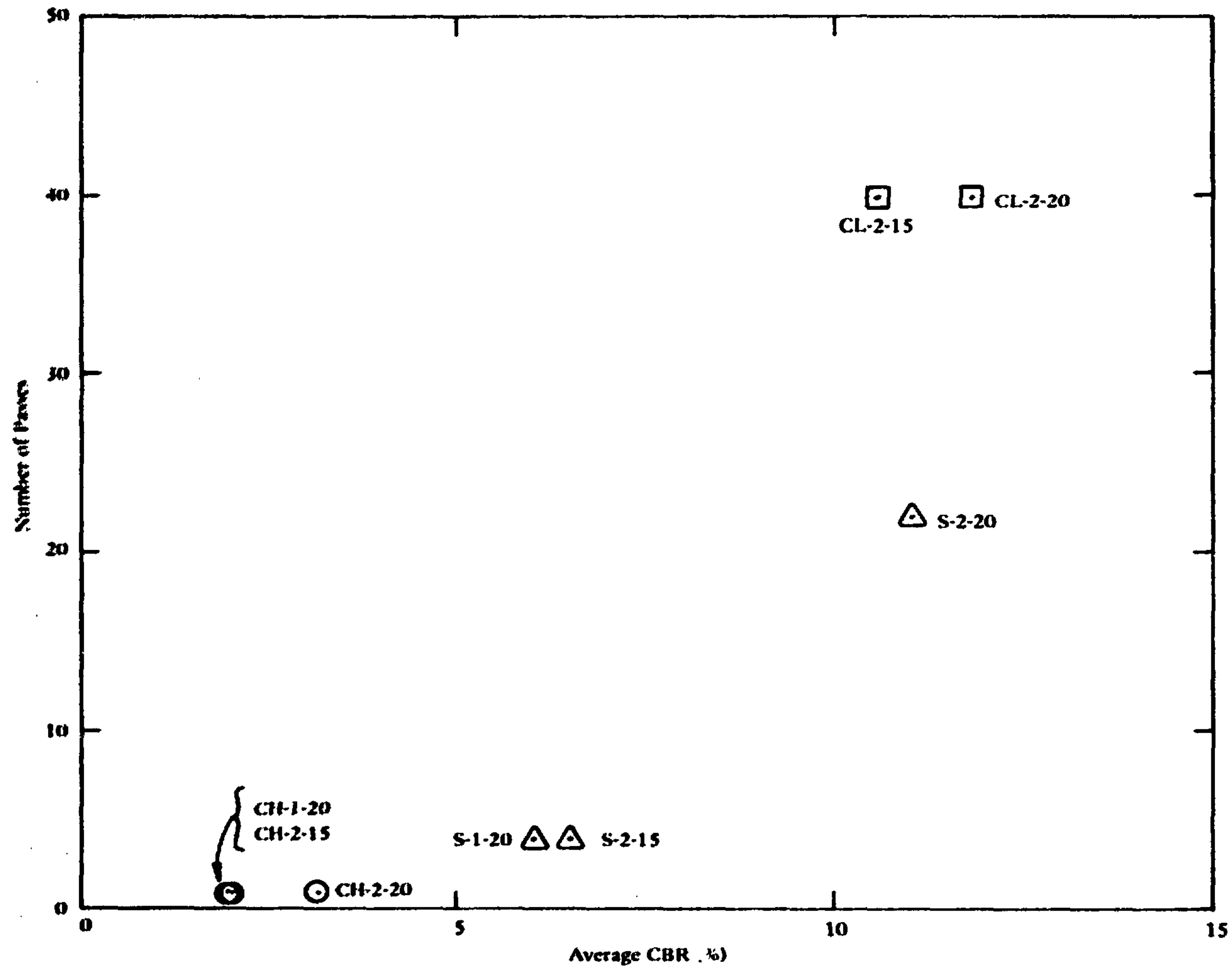

Figure 31. Number of passes of the trafficking wheel at which a deflection of 0.9 to 1.0 inch of the FOMAT surface was experienced versus the average of befcre and after traffic soil CBR.

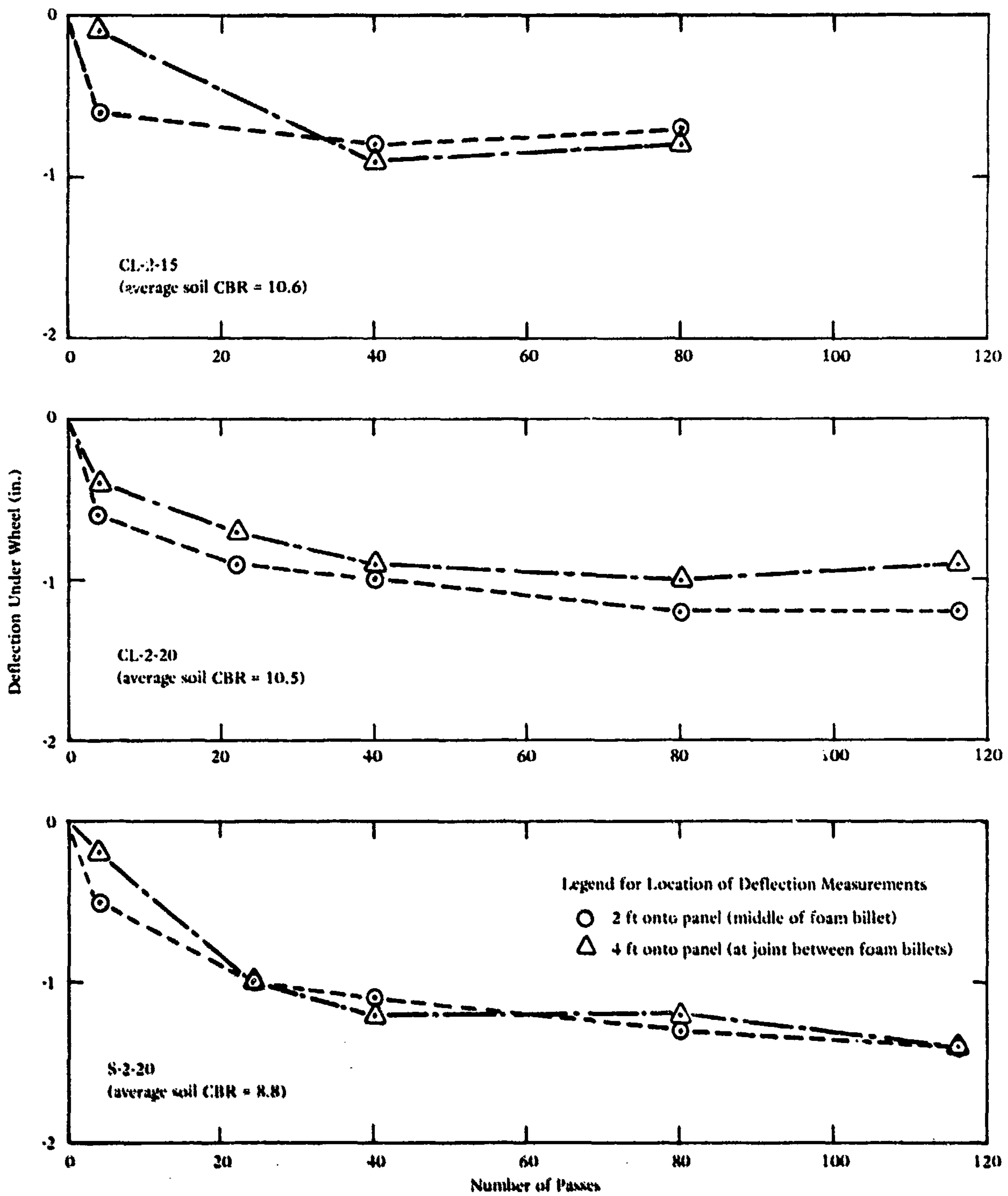

Figure 32. Deflection of the FOMAT surface under the wheel for FOMAT panels CL-2-15, CL-2-20, and S-2-20 at various numbers of passes of the wheel.

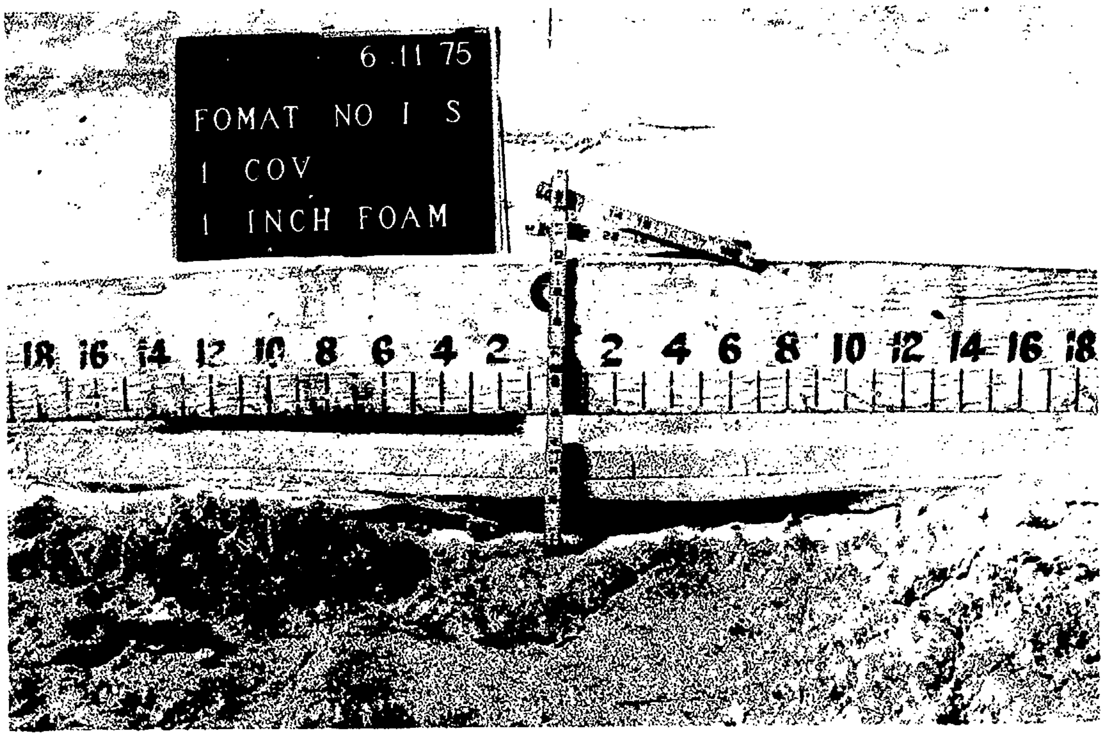

Figure 33. Cross section of FOMAT panel CH-1-20 after one pass of the wheel.

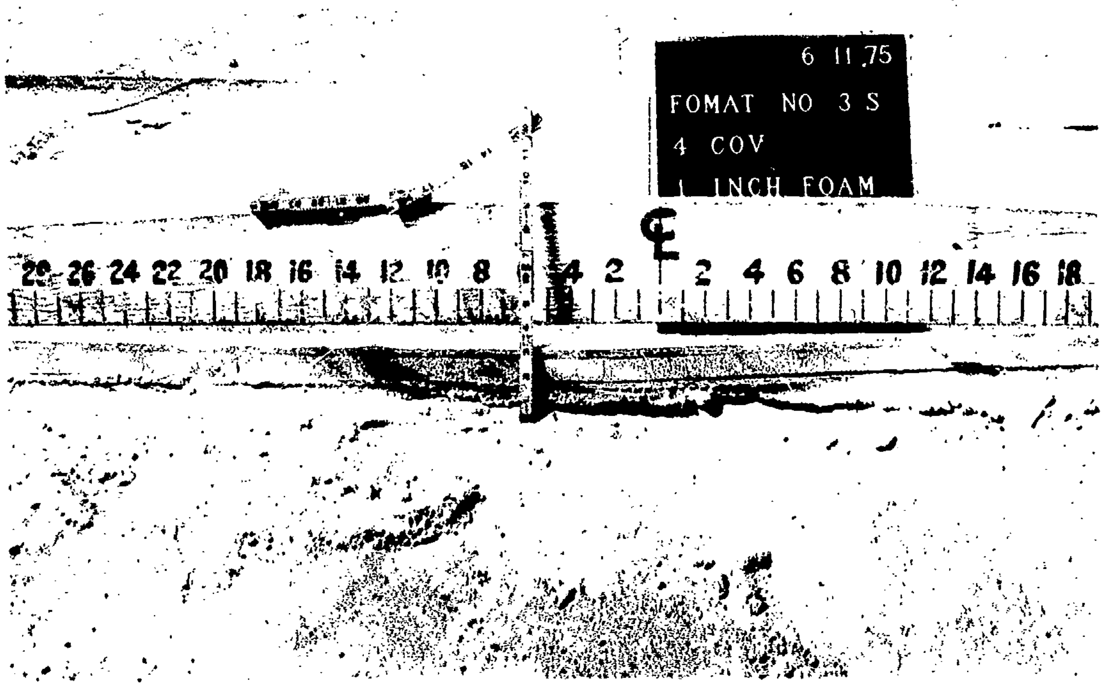

Figure 34. Cross section of FOMAT panel S-1-20 after four passes of the wheel.

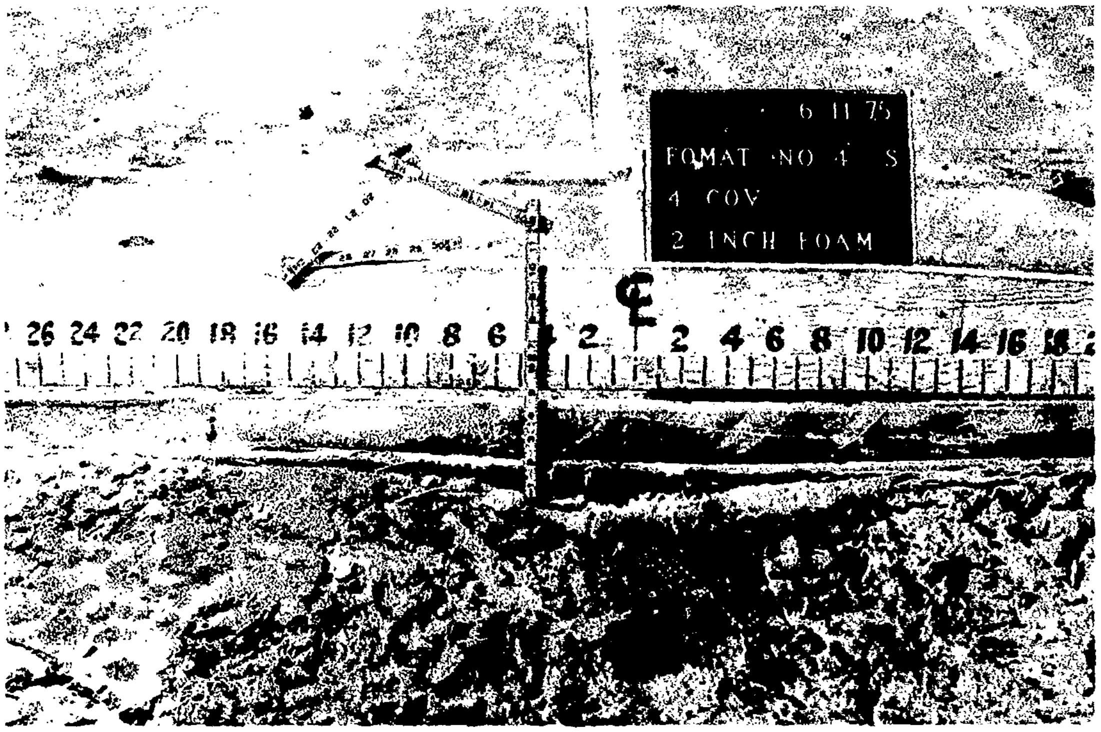

Figure 35. Cross section of FOMAT panel CH-2-15 after four passes of the wheel.

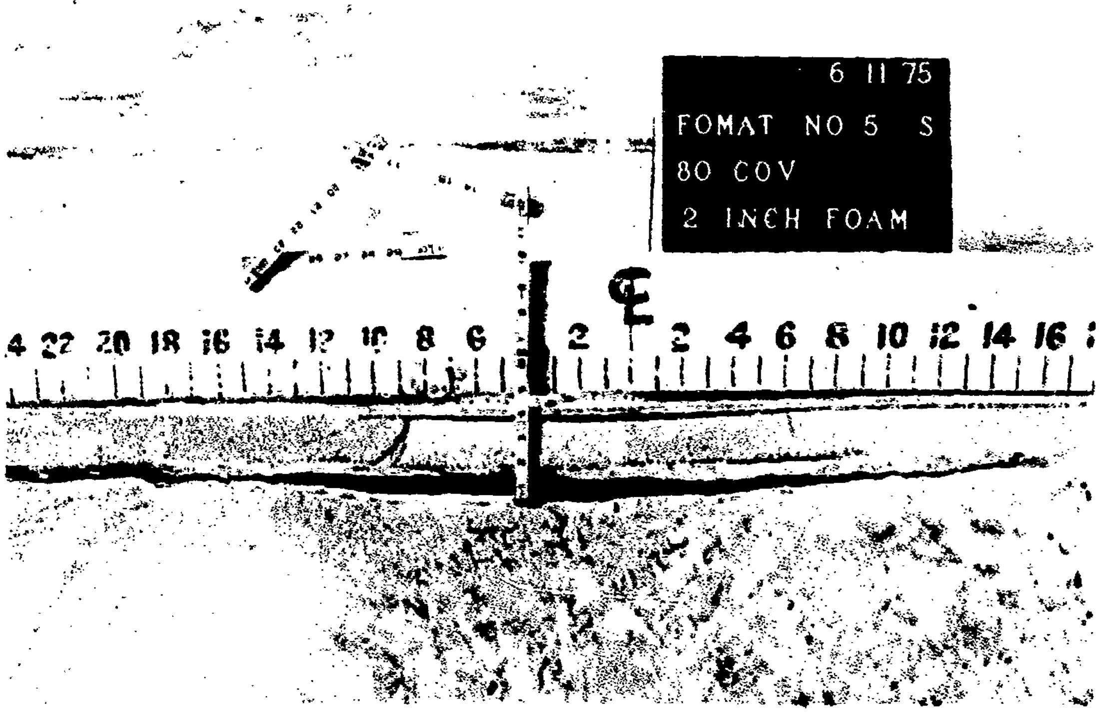

Figure 36. Cross section of FOMAT panel CL-2-15 after 80 passes of the wheel.

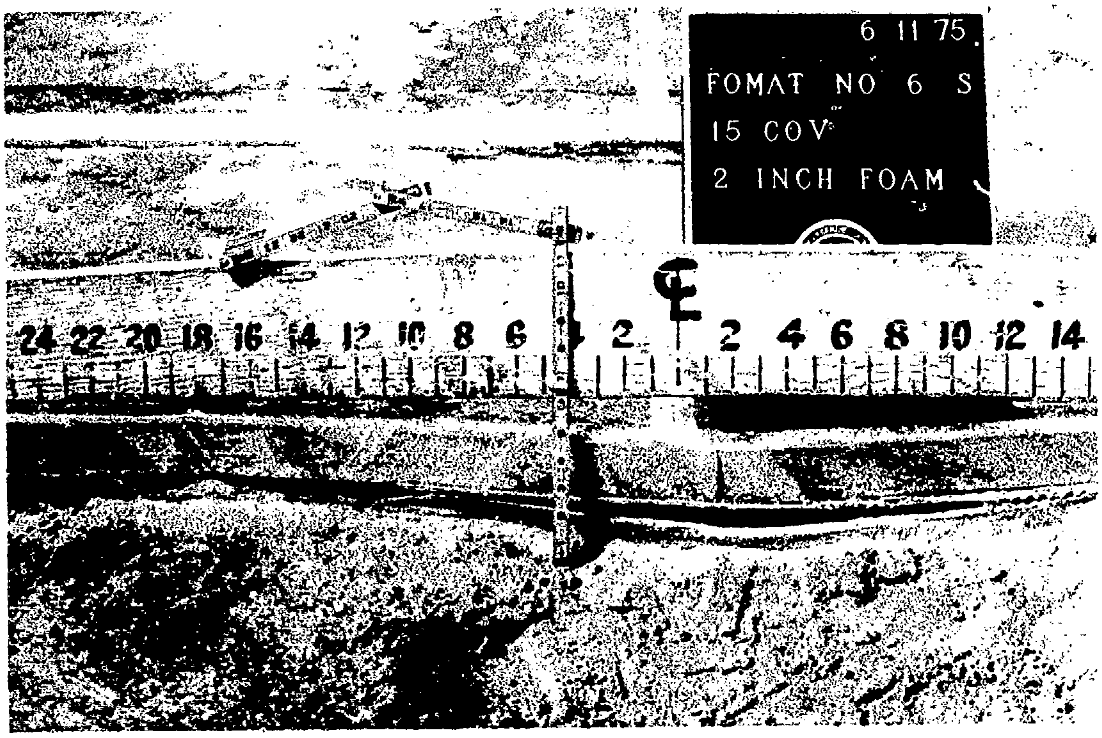

Figure 37. Cross section of FOMAT panel S-2-15 after 15 passes of the wheel.

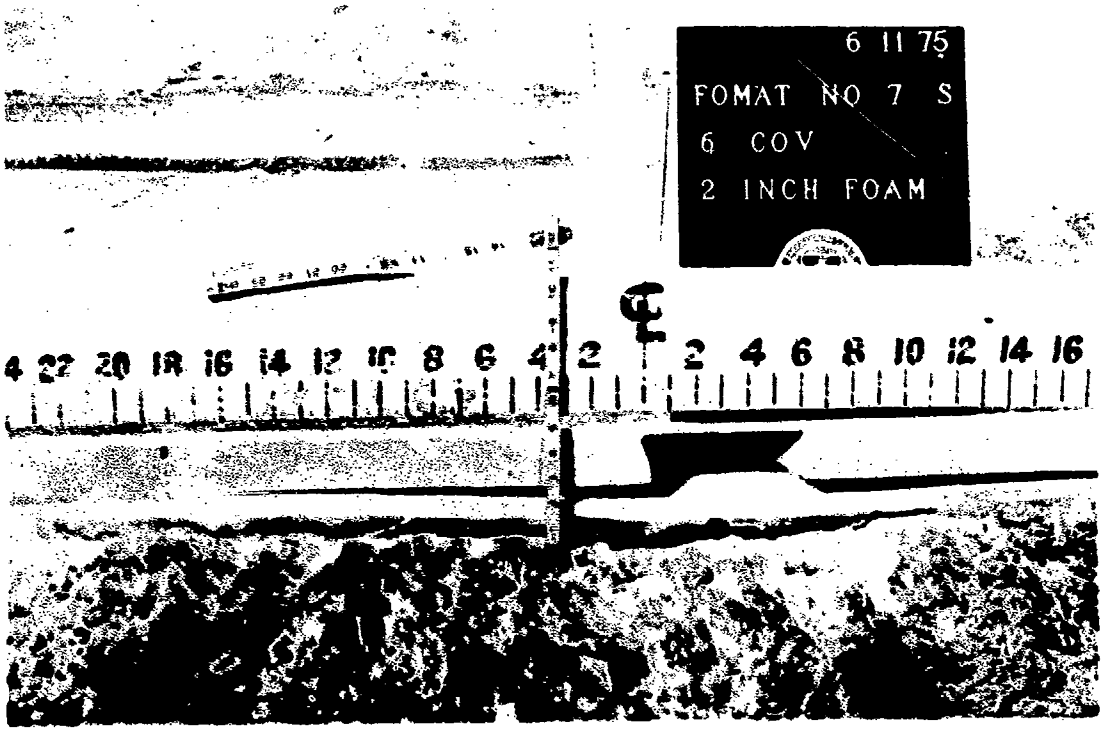

Figure 38. Cross section of FOMAT panel CH-2-20 after six passes of the wheel.

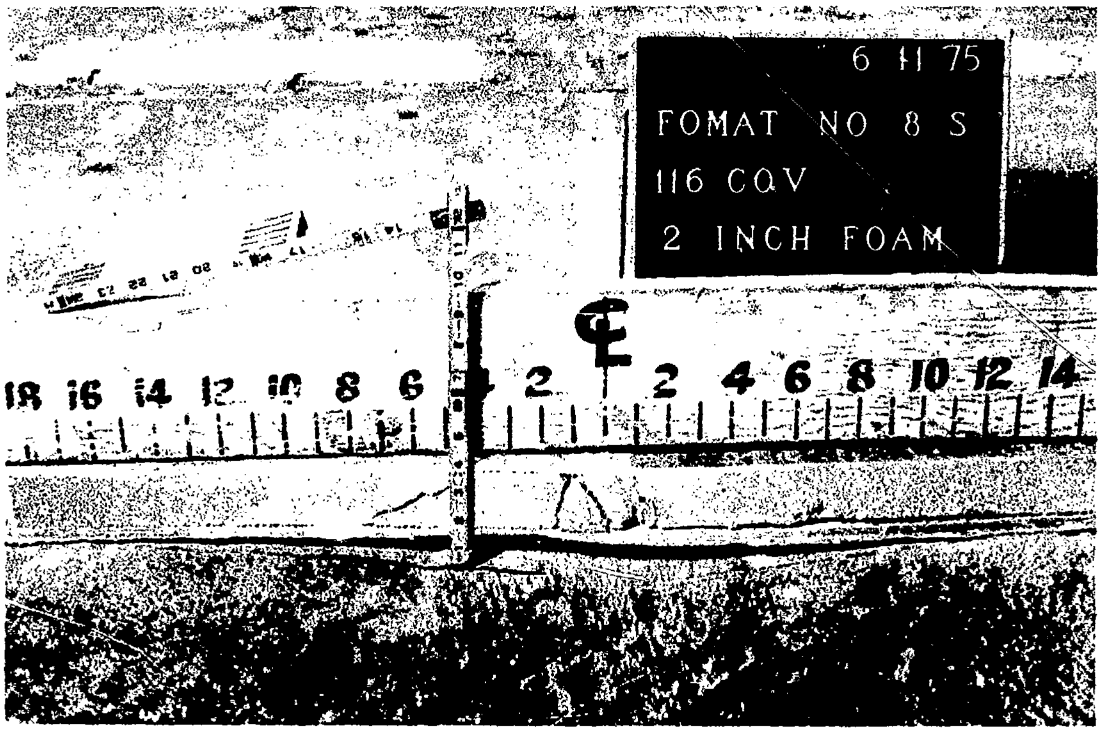

Figure 39. Cross section of FOMAT panel CL-2-20 after 116 passes of the wheel.

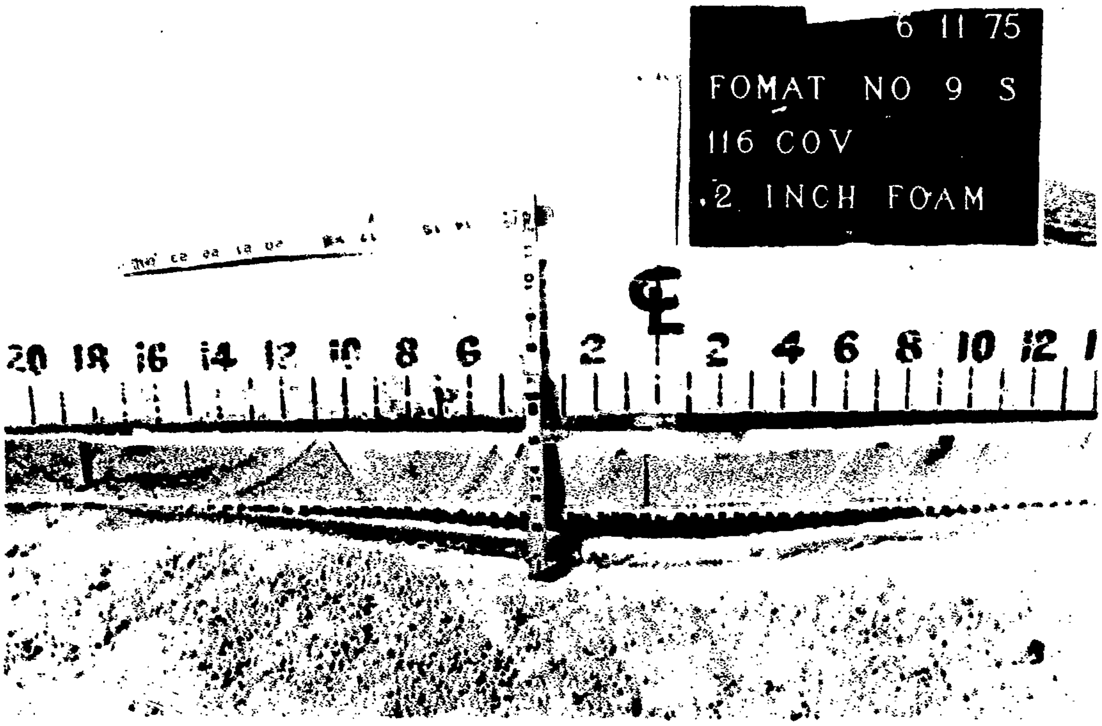

Figure 40. Cross section of FOMAT panel S-2-20 after 116 passes of the wheel.

Table 1. Material Components Used in FOMAT Fabrication

Material	Manufacturers[a]	Designation	Physical State At Delivery	Properties/Remarks
Polyurethane Foam Components	Upjohn Co.	Isonate CPR 739	Liquid (2 components in drums)	-
Fiberglass Matting	Fiberglass Industries	FABMAT C-4020	6-1/2-ft-wide rolls (105-ft matting/roll)	40 oz/yd^2 woven roving and 2 oz/ft^2 random fibers
Polyester Resin	PPG Industries Inc.	RS 50129	Liquid (in drums)	Contains 35% Styrene Monomer
Benzoyl Peroxide (Catalyst)	Noury Chemical Corp.	S-0046 Green	Liquid (in drums)	40% BPO by weight in inert carrier
Dimethylaniline (Promoter)	American Cyanamid Corp.	-	Liquid (in drums)	100% active dimethylaniline

[a]Listing of the manufacturer does not constitute endorsement of the listed product, but is made to identify the actual material used.

Table 2. Comparison of Ultimate Strength Values for the FRP and Foam Materials With Maximum Calculated Stresses From the Finite Element Computer Analysis

FOMAT Description	Soil CBR	Ultimate Strength/Maximum Calculated Stress Ratio[a] for -					
		Tension		Compression		Shear	
		FRP	Foam	FRP	Foam	FRP	Foam
20-pcf 2-in.-thick foam (1/4-in.-thick FRP outer layers)	4	2.6	19.0	2.5	4.6	13.0	2.6
	15	3.6	29.0	3.2	4.5	16.0	3.1
	50	8.7	90.0	5.5	4.4	28.0	10.2
10-pcf 2-in.-thick foam (1/4-in.-thick FRP outer layers)	4	5.2	very large[b]	4.8	1.1	4.6	1.7
	15	9.8	very large[b]	6.7	1.0	5.8	2.2
	50	172.0	very large[b]	12.8	1.0	9.2	3.7

[a]Ultimate strength values:

Material	Tension (psi)	Compression (psi)	Shear (psi)
FRP	15,000	15,000	12,000
20-pcf foam	630	1,150	500
10-pcf foam	240	250	180

[b]Calculated stresses are negligible; therefore, these values are very large.

Table 3. FOMAT Load Bearing Test in Mechanical Subgrade

(Diameter of plate, 12 in. Subgrade CBR, 6-8)

Load (lb)	Deflection (in.)				
	6 in.	9 in.	15 in.	22 in.	32 in.
5,000	0.005	0.038	0.022	0.009	-0.002
10,000	0.097	0.071	0.039	0.015	-0.006
15,000	0.144	0.105	0.057	0.021	-0.012
20,000	0.190	0.138	0.075	0.027	-0.016
30,000	0.279	0.202	0.110	0.039	-0.028
40,000	0.377	0.271	0.147	0.051	-0.038
50,000	0.474	0.338	0.181	0.060	-0.053
60,000	0.574	0.403	0.213	0.067	-0.069
70,000	0.674	0.469	0.245	0.073	-0.089
71,750[a]	0.710	0.492	0.256	0.073	-0.100

[a] Fiberglass cracking noise at this load.

Table 4. Temperatures Measured During Heat/Blast Tests by the Thermocouples Imbedded in Each FOMAT Panel

Panel No.	Exposure Temp °F	Cycle No.	Thermocouple, °F					Remarks
			1	2	3	4	5	
1	500	1	208	177	185	118	128	
		2	218	205	217	140	145	
		3	251	238	257	170	172	
		4	260	253	153	182	183	
		5	245	240	143	187	188	
1	750	1	192	137	175	127	115	
		2	223	168	231	168	155	
		3	240	205	260	198	168	
		4	247	212	270	213	189	
		5	258	229	292	232	207	
1	1,000	1	140	118	138	127	128	2-hr lapse time between cycles 6 and 7
		2	210	158	192	165	172	
		3	232	185	223	190	198	
		4	232	185	220	205	125	
		5	247	203	243	218	238	
		6	275	210	248	232	247	
		7	180	142	172	211	213	
		8	220	185	225	225	232	
		9	243	202	246	232	247	
		10	261	218	265	240	270	
2	1,000	1	90	207	147	77	74	Insulation of thermocouples burned off
		2	145	270	163	145	113	
		3	178	286	192	174	190	
3a	1,000	1	--	155	159	121	120	Coating blown off

(continued)

Table 4. Continued

Panel No.	Exposure Temp °F	Cycle No.	Thermocouple, °F					Remarks
			1	2	3	4	5	
4	500	1	122	89	80	85	95	
		2	145	155	100	102	115	
		3	173	199	103	132	137	
		4	192	212	-	158	169	
		5	205	225	-	170	172	
4	750	1	147	147	-	138	121	
		2	195	203	-	175	158	
		3	217	238	-	195	168	
		4	237	188	-	215	180	
		5	252	203	-	250	167	
4	1,000	1	142	91	-	112	110	
		2	192	153	-	155	150	
		3	230	171	-	190	178	
		4	228	190	-	195	182	
		5	245	212	-	208	200	
		6	256	226	-	218	212	
		7	274	241	-	228	226	
		8	288	256	-	237	235	
		9	289	268	-	237	237	
		10	297	278	-	237	242	
5[a]	1,000	1	90	89	100	95	100	
		2	122	135	133	152	155	
		3	163	162	157	189	187	
		4	204	198	182	215	212	
		5	222	207	203	235	227	
		6	227	217	229	242	226	
		7	241	229	239	250	237	
		8	240	239	255	256	242	
		9	256	256	270	263	248	
		10	270	268	282	271	259	

[a]Panels 3 and 5 were coated with Dow Silicone Rubber RTV 732 prior to testing.

Table 5. Results of Observations During and After Construction of FOMAT Panels

FOMAT Panel	During Construction	Post Construction (Before Traffic)
CH-1-20	Catalyst pump problems (top FRP layer)	Some crazing; yellow look indicated too much promoter and not enough catalyst.
S-1-20		Looks deficient in catalyst. Top FRP on western one-third of panel not bonded; also, small area on eastern edge looks like resin did not penetrate glass in these areas. Repaired by hand pour.
CH-2-15	Catalyst pump problems (bottom FRP layer)	Looks good, except over south-eastern-most foam billet where catalyst amount looks excessive.
CL-2-15		Except for air bubbles trapped beneath the fiberglass, this panel looks good.
S-2-15		Looks good.
CH-2-20	Switched resin containers (bottom layer)	Looks good.
CL-2-20		Looks good.
S-2-20	Resin from different containers used to spray each fiberglass layer for the bottom FRP layer.	Looks good.

Table 6. Results of Soil Tests Made Before and After Traffic

FOMAT Panel	Before Traffic				After Traffic[b]		
	CBR (%)	Dry Density (pcf)	Water Content (%)	Cone Penetration Index[a]	CBR (%)	Dry Density (pcf)	Water Content (%)
CH-1-20	1.9	83.2	33.3	2.0	2.0	83.3	32.4
S-1-20	6	109.8	7.5	6.2	4.7	[c]	[c]
CH-2-15	1.8	82.6	34.1	2.1	3.0	83.7	32.8
CL-2-15	10	94.5	18.6	11.2	11.3	97.8	18.1
S-2-15	7	110.3	6.6	6.0	3.0	[c]	[c]
CH-2-20	3.2	89.2	27.5	2.3	7.0	101.8	27.7
CL-2-20	10	97.1	18.2	13.5	11.0	100.6	18.4
S-2-20	12	113.5	9.3	10.0	5.7	[c]	[c]

[a] Readings obtained with Airfield Cone Penetrometer.

[b] Cone penetration index not measured after traffic.

[c] Readings were not taken.

Table 7. Comparison of Average Ultimate Beam Load Test Results From Field-Installed and Laboratory-Constructed Specimens

Soil Type Under FOMAT	Foam Thickness (in.)	Foam Density (pcf)	Average Ultimate Beam Load (lb)
Field Samples			
Heavy Clay	1	20	1,332
Heavy Clay	2	15	2,349
Heavy Clay	2	20	2,259
Lean Clay	2	15	845
Lean Clay	2	20	988
Sand	1	20	Bottom FRP unbonded on all samples over sand; therefore, beams could not be made for testing.
Sand	2	15	
Sand	2	20	
Laboratory Samples			
None (Lab sample)	2	15	2,978 (CEL)
None (Lab sample)	2	20	3,130 (WES)

Table 8. Subgrade Modulus as Determined From Plate Bearing Tests With a 12-inch Plate on the Surface of the Soil in Each Test Pit

Test Pit Identification	Soil Type	Subgrade Modulus (psi/in.)
CH-1-20	Heavy Clay	73
CH-2-15	Heavy Clay	78
CH-2-20	Heavy Clay	101
CL-2-15	Lean Clay	255
CL-2-20	Lean Clay	275
S-1-20	Sand	300
S-2-15	Sand	297
S-2-20	Sand	338

Table 9. Comparison of Calculated and Measured Values of Deflection and Ultimate Strength and Calculated Stresses of the Foam in Each FOMAT Panel Tested Under the F4 Traffic Wheel

FOMAT Panel	Deflections (in.)		Ratio of Foam Ultimate Strength/ Maximum Calculated Stress[a]		
	Measured[b]	Calculated	Tension	Compression	Shear
CH-1-20	0.75	0.82	2.2	2.5	1.5
S-1-20	0.41	0.50	3.8	3.1	2.2
CH-2-15	0.65	0.67	2.7	1.9	1.8
CL-2-15	0.49	0.48	3.7	2.1	2.2
S-2-15	0.50	0.45	4.0	2.1	2.3
CH-2-20	0.62	0.54	3.3	3.3	2.3
CL-2-20	0.28	0.40	4.3	3.6	2.7
S-2-20	0.33	0.38	4.7	3.7	2.8

[a] Ultimate strength values are:

Foam Density (pcf)	Tension (psi)	Compression (psi)	Shear (psi)
15	440	630	360
20	630	1,150	500

[b] These deflection values were obtained by extrapolating (except the last two values which were obtained by interpolating) the plots for plate bearing tests performed on each FOMAT panel.

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